Quantifying Transportation Emissions at Worcester Polytechnic Institute

An Interactive Qualifying Project Report

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Abstract

Worcester Polytechnic Institute (WPI) currently lacks an up-to-date inventory of Scope 3 emissions, which are indirect emissions produced by WPI operations. The goal of this project was to evaluate data and estimate carbon emissions produced by commuters associated with WPI. We distributed a survey to estimate the Scope 3 transportation-related carbon emissions of the respondents, extrapolated the results to represent the carbon emissions for the population of WPI, and used the results to make recommendations for reducing these emissions. The estimated total scope 3 carbon emissions from transportation at WPI was estimated to be over 10700 metric tons of CO2e. By quantifying travel emissions, WPI can take a step towards reducing its carbon footprint and promoting sustainable practices.

Acknowledgements

We would like to thank our advisors, Paul Mathisen and Nicole Luiz, for their unwavering support and guidance throughout the crafting of this project. We'd also like to acknowledge Karen Coghlan, our research consultant at WPI, for her assistance in finding appropriate sources for our paper.

Authorship

The collaborative writing process started with Brian Fox drafting most sections, then Bryan Silva edited and formatted every section. In general, most of the writing was initially done by Brian Fox, then most of the data science of the surveys, tables and figures, and analysis was done by Bryan Silva.

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1. Introduction

It is critical for an institution to evaluate and understand its carbon emissions in order to make its community and environment more efficient and safe. While many institutions are closely monitoring more direct emissions, such as emissions from boilers, furnaces, and other operational activities, few understand the nature of carbon emissions from indirect sources, also known as Scope 3 emissions. This category includes emissions related to purchased materials, employee travel, and waste disposal. More information on the different scopes of emissions can be found in section 2.2.

An increasing number of colleges and universities are recognizing the importance of Scope 3 emissions, but many still lack data regarding their Scope 3 emissions. While Worcester Polytechnic Institute (WPI) regularly evaluates its emissions, the university does not currently have an updated inventory of Scope 3 emissions. The most recent information on WPI's scope 3 emissions came from a survey conducted in a previous IQP in 2018 (Thein et al., 2018). Additional information on Scope 3 emissions is needed, such as staff, faculty, and student travel to and from WPI, including student project travel to project centers, which also represents a portion of the institution's Scope 3 emissions. By quantifying the emissions related to travel, WPI can make informed decisions about its environmental impact.

The goal of this project was to estimate carbon emissions produced by commuters associated with Worcester Polytechnic Institute in order to better understand how the community can reduce its carbon footprint. These commuters include all students, faculty, and staff commuting to the WPI campus, traveling to and from their homes during the academic year, traveling to and from their permanent residences during breaks, and faculty traveling to and from professional development events such as conferences or off-campus meetings. The scope of our project did not include travel to sporting events and activities, and travel to places in Worcester.

In order to accomplish the project's goal, our team developed a survey and sent it to students, faculty, and staff, with the mission to determine the most common forms of transportation used to commute to the WPI campus. This survey would determine how far away these commuters live during the year. Furthermore, it would collect their car type, the distance from their permanent residence to campus, and the frequency of travel. From this survey, our team estimated the total Scope 3 emissions generated from these modes of travel. With this number, graphics were designed to visualize the Scope 3 emissions generated per category, such as the Scope 3 carbon footprint of students. Furthermore, different charts were developed to visualize the footprint of Scope 3 emissions versus Scope 1 and 2 emissions measured on campus. A map was created to depict where these commuters lived during the academic year. Students, faculty, or staff members who wish to reduce their emissions, could refer to the notable alternative transportation options we explored and described in our project.

Not only did we plan to quantify Scope 3 emissions for the operations and sustainability departments at WPI, but our project also intended to educate the community about the indirect carbon emissions that are produced from a fully functioning university campus. Moreover, because individuals produce the emissions we measure, our efforts to change behaviors by sharing alternative transportation solutions may greatly reduce the number of harmful emissions produced in our community.

2. Background

Carbon emissions are harming our planet and our bodies. These emissions, for the sake of understanding an institution or company and its value chain, can be split into three scopes. In particular, scope 3 emissions will be elaborated on as our project attempts to quantify those emissions that are a result of the activities not directly controlled or operated by Worcester Polytechnic Institute. Not only has our team explored the various transportation surveys and projects completed by other institutions and organizations, but we have also explored the city of Worcester's history with transportation and greenhouse gases. Overall, the importance of quantifying emissions of transportation to and from WPI is crucial to better understand how we can help our community, our city, and our planet.

2.1 Carbon Emissions and Our Planet

Greenhouse gases (GHGs) are gases that cause heat to be trapped in our atmosphere. The primary greenhouse gas emitted through human activity is carbon dioxide (CO2), making up around 80% of the country's greenhouse gas emissions. In 2020, the U.S. outputted nearly 6,000 million metric tons of CO2 equivalent (CO2e) gas (US EPA, 2015). CO2e refers to the minority gases that are also measured such as methane and nitrous oxide, made equivalent to carbon dioxide. The combustion of gasoline and diesel in vehicles produces a quarter of the country's total greenhouse gas emissions. While processes such as the absorption of CO2 by plants and animals naturally remove some of this carbon dioxide, the gases produced by human activities outweigh natural CO2 production in the environment, causing an excess of CO2 in the atmosphere.

The Environmental Protection Agency (EPA) promotes certain ideas for reducing our carbon footprint relating to transportation. For example, they suggest traveling in the most fuel-efficient vehicles, reducing the distance traveled to reduce gasoline consumption, switching to fuels with less carbon content, and practicing carbon capture and sequestration (US EPA, 2015).

2.2 Defining Scope 1, 2, and 3 Emissions

The GHG Protocol is responsible for developing and distributing GHG accounting standards (*Greenhouse Gas Protocol*, n.d.). Their corporate standard defines emissions across a value chain into three categories. While Scope 1 includes all direct outputs of greenhouse gases into our atmosphere, Scope 2 and 3 emissions are indirect consequences of an institution.

Scope 1 is any direct emission from something owned or controlled by the company, such as emissions from boilers, furnaces, or company vehicles.

Scope 2 is any emission that results from company-purchased electricity. These emissions occur at the facility where electricity is generated. This is electricity purchased or brought into the domain of the organization.

Scope 3 emissions are indirect greenhouse gas emissions that are a consequence of the functioning of an institution, but are sources not owned or controlled by the company itself. Examples of scope 3 emissions include extraction of purchased materials, employee travel, and waste disposal.

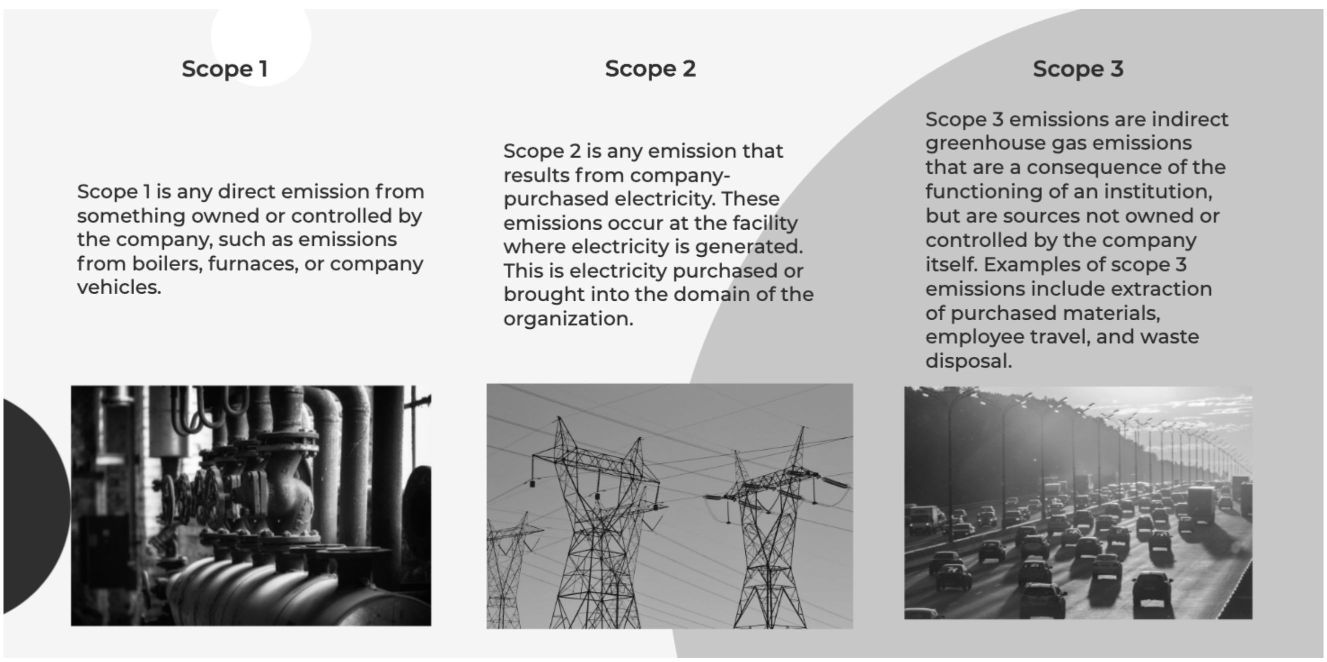


Figure 2.2 Definitions of the Scopes of Emissions

2.2.1 Scope 3 Emissions

Our measurement of Scope 3 emissions most directly relates to the definition by Second Nature, a nonprofit organization working with higher education institutions and their communities to commit to taking action on climate change and practicing sustainability. Second Nature defines the transportation aspect of Scope 3 emissions as “indirect emissions from (a) student, faculty, and staff commuting; and (b) institution-funded air travel". (Second Nature, n.d.)

Scope 3 emissions are divided into 15 different categories by the GHG Protocol, the most notable for this project are fuel and energy-related activities, business travel, and employee commuting. In order to calculate the emissions to satisfy the accounting of these emissions, the context of the activity is required, such as the quantity of transporting vehicles, a vehicle's standard emission output, and travel frequency. Other categories of Scope 3 emissions, such as the emissions produced within the purchasing and sales supply chain, such as product creation, delivery, and use at WPI, were not included within the scope of this project. Because our survey asks members of the WPI community about commuting, travel, and transportation, the scope of our project is limited to that portion of Scope 3 emissions. Often, due to the broadness and numerous categories that make up Scope 3 emissions, an institutions' Scope 3 emissions are generally the largest, yet hardest to measure, portion of its overall carbon footprint.

2.3 Health Effects of Vehicle Emissions

The emissions produced from car exhaust are known to cause negative health effects for the surrounding pedestrians and commuters who breathe it in. According to the United States Environmental Protection Agency, "Motor vehicle emissions contribute to ambient levels of air toxics known or suspected as human or animal carcinogens. Exposure to air toxics can also cause noncancerous health effects, such as neurological, cardiovascular, respiratory, reproductive, and/or immune system damage" (US EPA, 2016). Not only do vehicle emissions directly lead to increased rates of cancer in humans and animals alike, but studies have also shown that increased carbon emissions generally lead to increased rates of sleep apnea as well. A health survey done in a Boston area showed that people living in areas with higher carbon emissions have as much as a 30% increase in the risk of sleep apnea (Fang et al., 2015).

2.4 What Other Institutions Have Done

How have other institutions attempted to quantify their scope 3 emissions? There are many tools available for businesses or universities to calculate their emissions. Most calculation tools for scope 3 emissions operate on an estimation basis. One such calculator created by the California state government called Cool California estimates carbon footprints based on the region and size of the institution. The more sophisticated calculation tools that take many specific inputs such as SIMAP require a subscription but provide more accurate estimates for emissions, and categorize the carbon footprints in many categories such as transportation or heating, etc. (Valls-Val & Bovea, 2022).

By their nature, scope 3 emissions are difficult to reduce as they are emissions not directly controlled by an institution or company. These scope 3 emissions are not an issue exclusive to WPI. Thousands of universities are racing to become carbon neutral, meaning they release net zero emissions. It would be impossible to reduce scope 3 emissions to zero, so instead many institutions and companies resort to carbon offsets. According to a Second Nature article, "The idea is that offsets compensate for those emissions an entity continues to generate; in other words, equilibrium is achieved through penance. And climate penance, not unlike old-world Catholic dispensations from sin, can simply be bought" (*Inside Schools' Race to Carbon-Neutrality*, n.d.). Typically university carbon offsets are in the form of renewables such as wind farms or solar panels. Many also employ third-party companies to plant trees in an attempt to offset their carbon emissions. According to a 2017 STARS report, WPI only uses 0.13% clean or renewable energy in its total energy consumption (*Clean and Renewable Energy | Worcester Polytechnic Institute | Scorecard | Institutions | STARS Reports*, n.d.). Steps can be made to increase that number to offset the scope 3 emissions.

2.5 Successful Surveying of Commuters

2.5.1 University of North Carolina Commuter Survey (2019)

In 2019, the University of North Carolina (UNC) distributed a commuter survey to a random sample of UNC staff, faculty, and students (*UNC Commuter Survey*, 2019). Over the years of this survey being deployed, the questions have been refined to induce a greater response rate. Questions were close-ended and check boxes increased the response rate. Questions that required numerical answers were short answer boxes. In order to acquire the population, a random sample of faculty, staff, and students was chosen. An email would be sent to that random sample, and of that, UNC achieved high response rates. 32% of the random sample of faculty and staff took the survey and there was a 13% response rate for students. After the first email was sent with a link to the secure online survey, a reminder email was sent 7 days after. Microsoft Excel and Qualtrics were used to analyze the results of the survey.

When measuring the usage of modes of transportation among the subjects, UNC used a "mode split" which is essentially a ratio of the usage of modes of transportation. For example, if a student walks 40% of the time, drives alone 50% of the time, and bikes 10% of the time, the mode split for that student would be 0.40, 0.50, and 0.10 respectively. Other modes of transportation include bus, park and ride, carpool, and others. It also had respondents express their likeliness of using alternative modes of transportation or what incentives would be influential to change their mode of transportation. Finally, the survey collected the distance traveled via this mode of transportation in miles. Because it was only a survey, no calculation of vehicle emissions was calculated from this research.

2.5.2 Virginia Department of Transportation (DOT) Commuter Survey

The Virginia DOT conducted a commuter survey to better understand the lifestyle and behaviors of commuters in the state (*Lynnhaven/Oceana Transportation Needs Assessment Study*, 2000). Results from the survey informed the DOT with information regarding the work commute, perceptions about parking, willingness to share a ride to work, and incentives required to increase the likelihood of ride-sharing. The participants' commutes were measured in miles per one-way trip. While this survey also inquired about parking perception, it included trip-chaining, which is when commuters stop at businesses on their way to and from their final destination. For example, a commuter heading to work may stop at the grocery store on the way home. Their research found that through predictive modeling, 7% of single occupancy vehicle commuters may actually convert to an alternate mode of transportation.

2.6 Worcester and its Public Transit

Worcester, incorporated in 1848, is the second-largest city in Massachusetts. It has a population of 206,518 residents. The city is located in the center of the state, between Boston and Springfield. Worcester is home to 8 colleges and universities, including Worcester Polytechnic Institute. Spanning an area of around 38 square miles, the city of Worcester has several options for public transit (*Quick Facts | City of Worcester, MA*, 2022).

The Worcester Regional Transit Authority (WRTA) offers intra-city bus transportation, whereas Peter Pan and Greyhound offer inter-city bus service. The WRTA services the city of Worcester and 36 surrounding communities. As the second largest transit authority in Massachusetts, it is a reliable and inexpensive option for travel to work, shopping centers, school, and more. There are many all-electric and diesel-electric hybrid buses in the WRTA fleet (*Central and Worcester MA Public Transportation*, n.d.). Peter Pan and Greyhound buses offer several trips to locations outside of the city, with the most frequent trips being to Boston, Springfield, Providence, and Hartford (*Worcester - Union Station*, n.d.).

Yellow or Red Cab taxi services are available, and customers can receive pickup and drop-off services by contacting their number. Both the MBTA Commuter Rail and Amtrak train service Worcester. The Framingham/Worcester Commuter line brings commuters to stops from Worcester to South Station in Boston. Amtrak most often services travel to Hartford, Boston, and Albany.

Ride-sharing apps such as Uber or Lyft are options within the city. If a resident wishes to use their personal vehicle, there are several options for city parking. Several municipal parking garages and parking lots are available in more crowded areas of the city. Furthermore, street parking is available throughout the city. While the street parking surrounding WPI's campus is free, downtown Worcester utilizes a multi-space pay-by-plate parking model that is enforced from 8 a.m. to 8 p.m. Monday through Saturday.

2.6.1 Worcester and its Emissions

The City of Worcester produced a greenhouse gas inventory final report in 2019 (*Greenhouse Gas Inventory Final Report 2019*, 2019). Within this report, they included data suggesting that 27% of all city emissions can be attributed to "on-road transportation". This means that on-road transportation in Worcester generated 485,270 metric tons of CO2 emissions in 2019. Residential buildings (29%), commercial buildings (39%), and solid waste (8%) made up the other 1,361,600 metric tons of greenhouse gas emissions. The total emission output is 3% less than the output measured in the previous report 10 years earlier. However, when it comes to vehicle travel alone, the vehicle miles traveled per capita are up 17%, meaning individual greenhouse gas emissions from vehicle travel have increased over the past decade. The report also found that the carbon intensity levels are highest with combustion cars, whereas the city's offerings such as the WRTA and commuter rail are less intense.

2.7 Results of Previous Survey at WPI

According to the previous survey conducted within the WPI community in 2018, over 60% of WPI's emissions are from Scope 3. They had determined WPI's Scope 3 emissions to be almost 26,500 MT eCO2. They arrived at this result by collecting data via survey, then using Campus Carbon Calculator from the University of New Hampshire. As input into the calculator they used total distance traveled in miles, then the output of that calculator was MT eCO2. This process is very similar to what we will conduct for the project, with slight differences in the calculator, as well as what we will be taking into account for WPI's Scope 3 emissions. This previous survey also took into account air travel made by faculty and staff for conferences or other business-related travel, as well as air travel for international IQPs.

2.8 The Importance of Quantifying Emissions at WPI

Annual greenhouse gas measurements assist WPI to integrate carbon accounting into the decision-making processes of the institution and align their operations with their goals and values on where they lie in the grand scheme of contributing to a greener earth. Infrequent or irregular measurements of greenhouse gases would suggest that they are irrelevant to the institution and contradict the importance they assigned to them in their sustainability plan crafted in 2018. Within this 2020-2025 sustainability plan, the guiding principle of environmental stewardship suggests that this project's work is integral to the WPI plan to reduce greenhouse gas emissions and achieve carbon neutrality (*Sustainability Plan - WPI*, 2020). It is important to quantify the emissions at WPI in order to even begin reducing them.

3. Methodology

The goal of this project was to evaluate data regarding carbon emissions produced by travelers associated with Worcester Polytechnic Institute in order to better understand how the community can reduce its carbon footprint. We planned to invoke the use of unbiased surveying of the population of WPI. Those surveyed include faculty, staff, and students, and are referred to in this project as members of the WPI community, Below are the objectives needed to accomplish our goal for the project.

1. Create a survey to send to the WPI community, with the mission to:
    a. Determine what the most common forms of transportation used to commute to the WPI campus are.
    b. Determine the distance students, staff, and faculty commute to and from campus.
2. Estimate the Scope 3 emissions generated from these modes of travel to and from the WPI campus using a carbon footprint calculator
3. Design visualizations for the Scope 3 emissions generated by category, such as commuter emissions related to miles traveled, and create a map to visualize where members of the WPI community commute from
4. Communicate our findings to the WPI community in a format that is easily accessible and digestible
    a. Developing a flier for students
    b. Develop a presentation to demonstrate our findings to the proper departments and groups of individuals

3.1 Conducting a Survey

The method of collecting data related to Scope 3 emissions was a 10-15 minute Google Form survey, shared via QR code. The questions helped us to quantify WPI's scope 3 emissions from commuters, they involved what types of vehicles (if any) people are using on a daily or weekly basis. More questions such as how long the distance traveled usually, as well as how frequently that distance is traveled were beneficial as well as the fuel type and average gas mileage of each vehicle. We also wanted to know where the commute is starting from and going, so that we may be able to create visualizations of the geographic data, such as heat maps of emissions.

We then used this data and extrapolated it for the total population of WPI then imputed those numbers into a carbon calculator spreadsheet to estimate our Scope 3 emissions. We also produced a visualization similar to one that had been made in 2018. Then based on our research and results we shared suggestions on how to reduce or offset these emissions.

3.1.1 Survey Design

The purpose of the survey was to obtain information to input into a carbon calculator to calculate the scope 3 emissions from commuters at WPI. In order to create and publish a survey to our community, our team designed an informed consent document and took note of the risks associated with our project. While we don't expect any personally identifiable information to be at risk of getting leaked, it is important to educate the participants of our project that the information they provide us will not be directly referenced. When creating the survey, our team considered the potential benefits participants have from taking our survey. We envisioned participants critically thinking about their carbon footprint and the alternative transportation solutions that exist. Our survey is crafted to help us understand the community's opinion on commuting and transportation options.

It is critical to avoid bias when creating the survey as well as when recording responses. There are many types of biases that can occur in an experiment so our goal when we designed the survey was to minimize all biases. The first thing to account for is the wording of questions in the survey. We don't want to affect the subject's decisions in the survey in any way. The questions need to be clear and concise, avoiding jargon so as to not make the subject answer something different than what is needed. The next bias would come from sampling bias, which we avoided by distributing the survey to every demographic in the WPI community. Paper QR codes were posted across campus in as many different places as possible to try to obtain data from every type of commuter and every type of background. While we did not differentiate between different backgrounds, it is possible that different backgrounds have their own biases when it comes to commuting or the environment, so it's important to account for every background to ensure the sample is representative of the population of WPI. One final type of bias we tried to avoid was selection bias when presenting our results. We did not omit any details in our results, everything we have shown is everything we have done and found.

3.2 Estimating Scope 3 Emissions

After collecting the data from our survey, we input the information into a spreadsheet that we designed ourselves. The EPA provides guidance to help quantify carbon footprints based on mileage traveled. In order to calculate the emissions produced from certain modes of transportation, the following calculations were utilized:

Car

The amount of carbon dioxide emitted per gallon of gasoline burned is 0.00887 metric tons. Total gas emissions consider gases like carbon dioxide, methane, and nitrous oxide. If a survey participant did not specify their car's miles per gallon, the 2019 national average of 22.1 MPG, provided by the EPA, was used, but if a survey participant did specify their car's MPG then that value was used in place of 22.1 MPG in the final calculation (US EPA, 2015).

$$miles\ traveled \times \frac{1}{22.1\ MPG} = 0.0452\ gallons$$

$$0.0452\ gallons \times \frac{8.887\times10^{-3} metric\ tons\ of\ CO2e}{1\ gallon} =$$

$$4.017 \times 10^{-4}\ metric\ tons\ of\ CO2e\ per\ passenger\ mile$$

Calculation 1a.

Plane

Carbon Independent, an organization that quantifies the carbon footprint of popular human activities (*Aviation Emissions*, 2007), recommends using an average of 250 kg CO2e per passenger per hour for aviation travel. Based on the occupancy rates of the most popular airplanes, 107 passengers can be assumed as the average. The following calculations were performed to arrive at a final formula to determine the carbon emissions of aviation travel per passenger mile.

$$115g\ per\ passenger\ per\ km\ \times \frac{1\ mile}{1.609\ km} = 71.47g\ per\ passenger\ per\ mile$$

$$71.47g\ per\ passenger\ per\ mile\ \times\ \frac{1\ metric\ ton}{10^{6}g} =$$

$$7.147\ \times 10^{-5}\ metric\ tons\ per\ passenger\ per\ mile$$

Calculation 1b.

<u>Train</u>

According to research done by the US Department of Energy, trains emit 177 grams of CO2e per passenger per mile. The journalists at Governing explain these calculations and demonstrate that trains produce some of the lowest carbon emissions (*Are Trains or Buses Better for the Environment?*, 2022). Refer to calculation 1c below to arrive at a value for metric tons of CO2e per passenger mile.

$$177\ grams\ of\ CO2e\ per\ passenger\ per\ mile\ \times 10^{-6}\ \frac{metric\ tons}{grams} =$$

$$1.77\ \times 10^{-4}\ metric\ tons\ of\ CO2e\ per\ person\ per\ mile$$

Calculation 1c.

<u>Bus</u>

From the survey results, buses accounted for a statistically insignificant percentage of responses so it will not be included in further analysis, however it is important to note that buses are used widely across the world and are a popular alternative to driving a car everyday. According to the same research done by the US Department of Energy, buses on average emit 299 grams of CO2e per passenger mile. While not as efficient as trains, buses are still a relatively efficient transportation method compared to the average car. Below is a calculation to arrive at a value for metric tons of CO2e per passenger mile.

$$299\ grams\ of\ CO2e\ per\ passenger\ mile\ \times \frac{1\ metric\ ton}{10^6\ grams} =$$

$$2.99 \times 10^{-4}\ metric\ tons\ of\ CO2e\ per\ passenger\ mile$$

Calculation 1d.

3.3 Visualizing Data with a Transportation Map

In order to visualize the distance of commutes among members of the WPI community, a heatmap was created to show the relative distance that staff and faculty are commuting from. Below is the heatmap of the counties nearby Worcester that the survey respondents commute from.

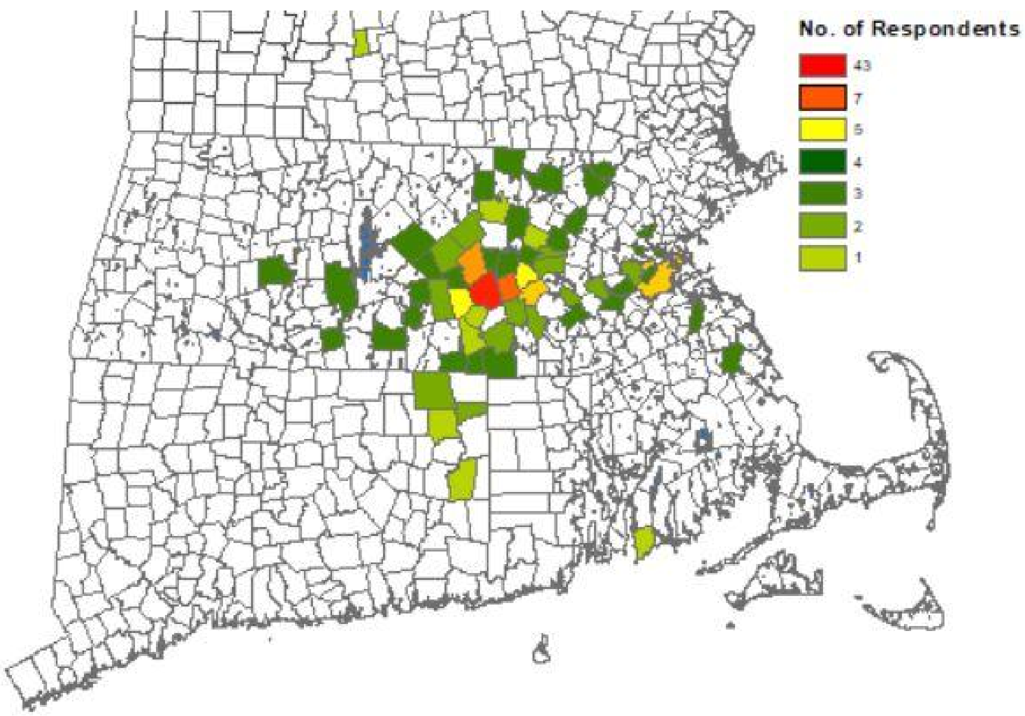


Figure 3.3.1 WPI Staff and Faculty Commuting Heatmap Based on Survey Results

The WPI website also provides a heatmap of where students' permanent residences are in the US which can be seen below in figure 3.3.2.

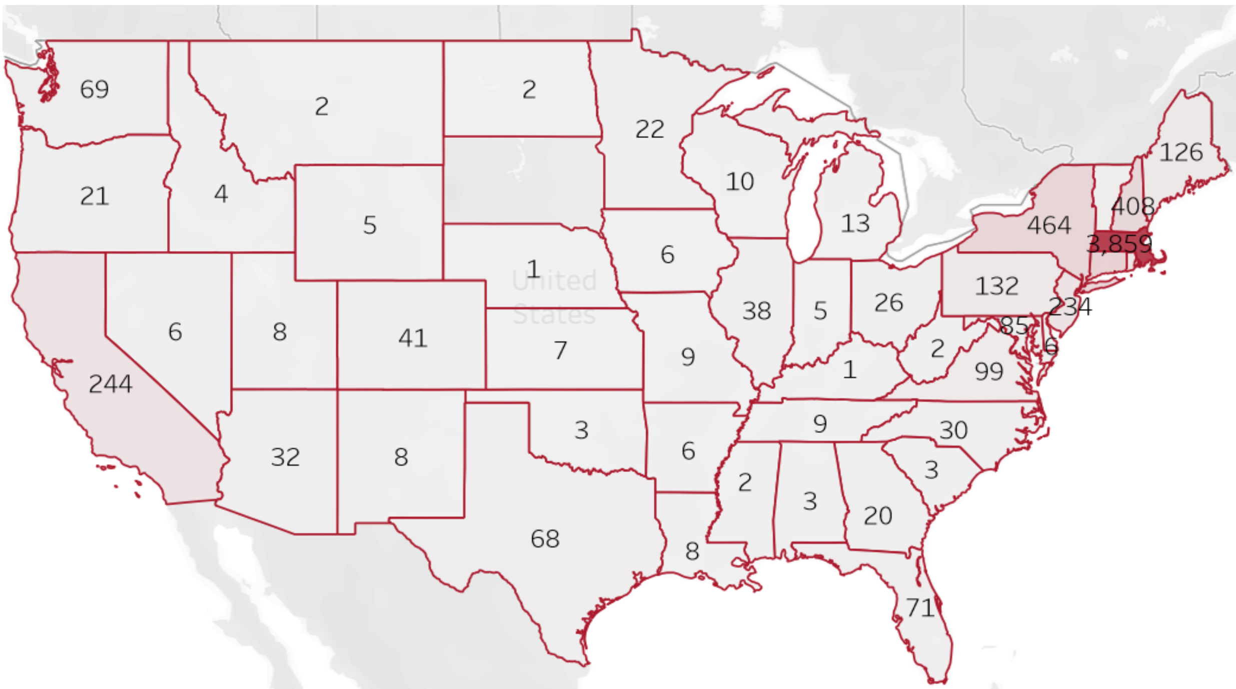


Figure 3.3.2 WPI Student Residence Heatmap

3.4 Communicating Results

After our survey was completed and we analyzed the results from our survey, our final goal was to communicate findings in an accessible and digestible way. We created two deliverables that we would share across the community.

3.4.1 Flyer for Students

Our team created a flier to share with all students. The flier contains important data collected by our project such as the carbon footprint of the student population, the negative health effects of greenhouse gases, and ways to reduce your carbon footprint. Also listed on the flier are notable alternative transportation solutions that we collected. This flier can be found in appendix B.

3.4.2 Presentation for Office of Sustainability and other WPI Departments

The presentation for the office of sustainability and other WPI departments was designed to help faculty and staff better understand this IQP. The presentation demonstrates our findings in order to better educate the professionals that work on campus. The goal of this presentation is to increase awareness about staff and faculty carbon footprint and suggest ways of reducing your carbon footprint. The presentation also suggests the use of alternative transportation and its benefits.

4. Findings

Our findings section is split into two subsections. In section 4.1, we included any findings related to commuting via car or bus within the community. This includes undergraduate students, graduate students, faculty, and staff traveling using cars or buses. We received an insignificant number of participants using buses on a regular basis. In section 4.2, we included travel using planes and trains to and from WPI’s campus. This includes undergraduate students, graduate students, faculty, and staff traveling between their permanent residences, local residences, or homes using planes or trains. Each section contains the total carbon emission and carbon emission equivalencies output per group, calculated in metric tons per year. Furthermore, section 4.2 focuses on IQP travel for students by plane for off campus IQPs.

4.1 Vehicle Travel Findings

The commuter findings include travel by undergraduate students, graduate students, faculty, and staff from their local and permanent residences to campus using a car. In the survey, each participant was asked to describe the mode of transportation they use to get to campus, the miles per gallon (MPG) per week of that mode of transportation, and how frequently that mode of transportation is used. Any participant that did not specify the MPG of their vehicle was marked as using a vehicle with the national average of miles per gallon, 22.1 MPG (see section 4.2).

4.1.1 Travel Statistics

Table 4.1.1 shows a statistical summary of the metric tons of CO2e per person per year for each transportation type. Buses and electric vehicles are not shown because the sample size was insignificant in the survey responses. The final column includes our findings on travel to and from IQP project center sites.

Table 4.1.1 Statistical Summary of Travel Emissions by Vehicle

Unit of Measurement: Metric Tons of CO2e per Person per Year

	Student Car	Student Train	Student Plane	Staff and Faculty Car	Staff and Faculty Train	Staff and Faculty Plane	Carbon Emissions Per Person for IQP Travel by Plane
Mean	**0.95**	**0.00**	**0.01**	**2.20**	**0.01**	**0.26**	**0.401**
Min	0.03	0.05	0.00	0.06	0.10	0.00	0.033
Max	6.97	0.05	1.58	8.56	0.20	3.57	1.50
Range	6.94	0.00	1.58	8.50	0.10	3.57	1.47
Standard Deviation	1.61	0.00	0.43	1.87	0.04	0.63	0.253

4.1.2 Vehicle Carbon Emissions Summary

By using the formula to calculate car emissions per year per person (calculation 1a.), we calculated the total CO2e travel emissions in metric tons per year for the total WPI community of students, staff, and faculty. These carbon emissions were produced from the car travel that happens daily between local and permanent residences and campus. Reasons for travel may include getting to class, to work, to meetings, or to club and social events.

Our 2022 population used to extrapolate our data was a total undergraduate and graduate student body of 7,308 and 1,362 total staff and faculty.

Table 4.1.2 Travel Emissions by Car for the 2022 Population

Student CO2e emissions (metric tons/year)	**Staff & faculty CO2e emissions (metric tons/year)**
6950	**2960**

Table 4.1.3 Travel Emissions Per Person By Car

Student CO2e emissions (metric tons/person/year)	Staff & faculty CO2e emissions (metric tons/person/year)
0.95	2.2

4.2 Plane and Train Travel Findings

Plane and train findings include any travel by undergraduate, graduate, faculty, or staff members using a plane or train. In the survey, each participant was asked to describe the type of transportation (plane or train), and how frequently that mode of transportation is used.

It is important to note that, because of our survey's low response rate regarding train and plane travel, we have a lack of data to confidently make claims about the emissions produced by WPI's community by plane or train travel. However, we still made estimates of the emissions produced using extrapolation methods.

4.2.1 IQP Travel Statistics Summary

At WPI, students have opportunities to travel off campus to complete their Interactive Qualifying Project (IQP). There are project centers all around the world and across the USA, some of them are close enough to drive or take the train such as the Boston project center. But the project centers that are further away require travel by plane. Last minute we had received a spreadsheet containing the location of the project centers and how many students were enrolled in each project center. To calculate the scope 3 emissions related to these project centers, a single round trip flight was assumed. First the distance from Boston Logan airport to the project center's closest airport was found with various travel agency websites. That distance in miles would be multiplied by 2 to find the total distance because of the round trip, and finally the same formula as used earlier for plane travel in section 4.2 was used to find the metric tons of CO2e. The total scope 3 carbon emissions related to IQP travel for 2022 is 623 metric tons of CO2e.

Refer to table 4.2.1 for a statistical summary of the metric tons of CO2e per person related to off campus IQP travel.

Table 4.2.1 Statistical Summary of Carbon Emissions Per Person for IQP Travel by Plane in 2022

Statistics	Metric tons of CO2e per person
Mean	0.401
Min	0.033
Max	1.50
Range	1.47
Standard Deviation	0.253

4.2.2 Plane and Train Carbon Emissions Summary

By using the formulae to calculate plane and train emissions per year per person (calculation 1b. and 1c. Located in section 3.2), we calculated the total CO2e emissions in metric tons per year for the total WPI community of students, staff, and faculty. These carbon emissions were produced from the longer-distance travel that happens more infrequently between permanent residences and local residences. Reasons for this travel may include going home for vacation or visiting friends and family.

Our 2022 population used to extrapolate our data was a total undergraduate and graduate student body of 7,308 and 1,362 total staff and faculty.

Table 4.2.2 Travel Emissions by Train and Plane for the 2022 Population

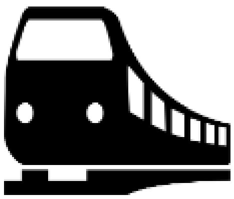
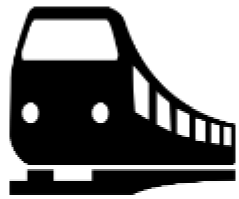
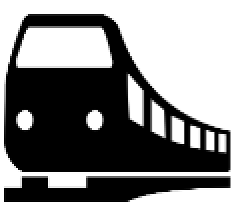
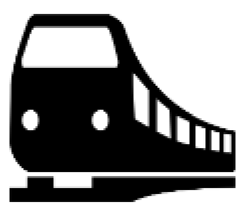
Student CO_2e emissions (metric tons/year)	Staff & faculty CO_2e emissions (metric tons/year)
 **0.094**	 **1.50**
 **14.6**	 **164**

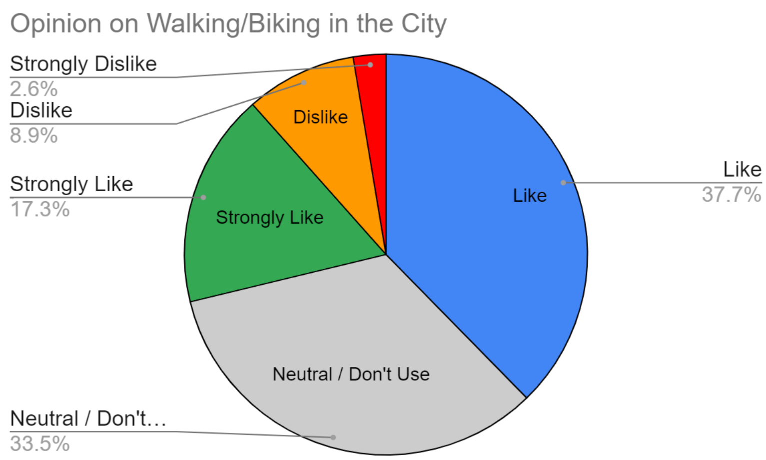
Table 4.2.3 Travel Emissions Per Person By Train and Plane

Student CO_2e emissions (metric tons/person/year)	Staff & faculty CO_2e emissions (metric tons/person/year)
 **0.001**	 **0.008**
 **0.009**	 **0.261**

4.3 Survey Results Visualized - Opinion Section

Our final section in the survey included questions to gather data regarding community member opinions on city walking and riding, campus shuttle services, and parking. Generally, while over a third of members of the community do not walk or bike often in the city, those that do enjoy it.

Figure 4.3.1 Opinion on Walking/Biking in the City



Figures 4.3.2 and 4.3.3 show opinions on parking for both students as well as staff and faculty. The general opinion for student parking is mixed with a little over half of the responses having a negative opinion and less than half were positive. However, for staff and faculty parking, the general opinion is mostly positive, with over 80% of the responses having a positive opinion.

Figure 4.3.2 Opinion on Resident Parking Options

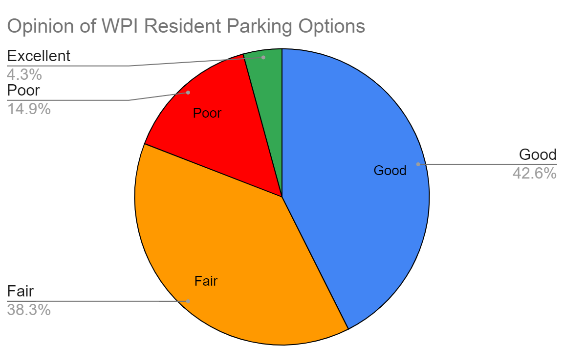
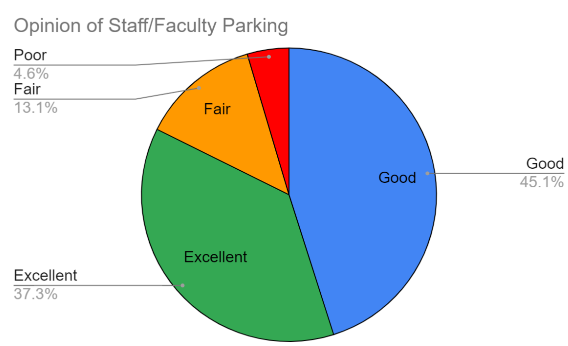


Figure 4.3.3 Opinion on Staff/Faculty Parking



5. Conclusions and Recommendations

5.1 Conclusions

The estimated total transportation emissions of WPI is over 10700 metric tons of CO2e. As a community, it is estimated that WPI undergraduate and graduate students produce more than 6900 metric tons of carbon dioxide emissions per year by car. This may include car or bus travel to and from campus or to and from their permanent residences. It is estimated that WPI staff and faculty produce more than 2900 metric tons of carbon dioxide emissions each year by car. This may include car or bus travel to and from campus from their permanent residence for work or meetings.

For perspective, the average US household produces 7.5 metric tons of CO2e powering their homes every year (*Picturing a Ton of CO2*, 2007). In table 4.1.3 in section 4, students at WPI emit an estimated average of about 1 metric ton of CO2e per year just by driving to campus. Therefore, the travel emissions for every 7 or 8 students are roughly equivalent to the CO2e required to power the average American household.

5.2 Recommendations

5.2.1 Educate WPI Community on their Carbon Footprint

Commuting to and from campus is a part of daily life for most students, faculty, and staff. While we may not be able to limit the number of times an individual is required to visit campus, we do encourage the institution and the community that make up the institution to consider their carbon footprint, and understand the impact it has on our planet. It is not only important to demonstrate the carbon emissions our community produces each year from travel and commuting, but also there is importance around the general idea of reducing your carbon footprint overall. Part of our deliverables for this IQP was an infographic flier with statistics on the community's carbon emissions and suggestions for how to reduce those emissions. While our deliverables were designed with specific transportation related solutions and alternatives, we also encourage the community to find ways to limit their carbon dioxide output. For example, the State of Massachusetts' website has a list of 10 ways you can start reducing your carbon footprint. For example, just by being mindful of the temperature in your house can reduce CO2 produced by 2,000 pounds (*Reduce Your Carbon Footprint at Home | Mass.Gov*, n.d.).

5.2.2 Transportation Best Practices and Awareness of Alternatives

It is estimated that over 500 students use a car to travel between their local residence and campus, which are often substitutes for walks that would be less than 15 minutes. By increasing the number of students who walk, carpool, or use mass transit, we can reduce emissions significantly. Carpooling with one other person instantly cuts your personal emissions for that trip in half. Ensure car tires are inflated properly. For each pressure unit under the recommended level, your car's fuel efficiency decreases. Newer, high efficiency vehicles and electric cars also will limit your carbon emission output (Carbon Footprint Factsheet, 2021). For staff and faculty traveling from out of state towns and cities, the commuter rail to Worcester is a popular and sustainable option. Taking the train means you are only contributing 40% as much emissions as you would by taking a car to work. Commuter rail stations are located across the state and are available in major parts of other states like Providence, Rhode Island.

5.2.3 Incentives for Green Transportation

We recommend the use of incentives to encourage green transportation. Examples of this may include special low-emission vehicle parking spots, financial rewards for using certain modes of cleaner transportation, and more EV charging stations on and around campus to encourage the use of electric vehicles and save drivers' time and money on the cost of gasoline.

A successful example of a clean transportation incentive can be seen by the State of Massachusetts' electric vehicle funding program. The MOR-EV Rebate Program gives rebates for those who choose to purchase and lease battery electric vehicles, fuel-cell electric vehicles, and plug-in hybrid vehicles (*MOR-EV | Center for Sustainable Energy*, 2023). Furthermore, the Massachusetts Department of Environmental Protection provides grants to public colleges and universities to acquire electric vehicles and charging stations (*Apply for MassEVIP Fleets Incentives | Mass.Gov*, 2023). While these are examples of government-funded incentive programs, we recommend WPI considers its own incentives to reduce its community's greenhouse-gas impact.

5.2.4 How to Improve Future Scope 3 IQPs

In the future, it would be much easier and more accurate if students and staff and faculty kept a record of their commutes as well as their flights. Currently projects have to rely on survey responses that contain estimates from the respondents that are likely inaccurate. Increasing response rate is another way to improve the accuracy of results. The closer a survey is to collecting the entire population, the less error there will be when extrapolating the data. And we believe one of the easiest things people can do in the future is keep the survey short. If the survey is too long, people will get bored and will not put effort into their answers, which leads to inaccurate data. By developing effective surveys and obtaining more accurate estimates of scope 3 emissions, WPI can reduce its scope 3 emissions contributing to WPI's commitment to sustainable practices and reduce its overall carbon footprint.

6. Appendix

Appendix A: Calculations

$$miles\ traveled \times \frac{1}{22.1\ MPG} = 0.0452\ gallons$$

$$0.0452\ gallons \times \frac{8.887 \times 10^{-3}\ metric\ tons\ of\ CO2e}{1\ gallon} =$$

$$4.017 \times 10^{-4}\ metric\ tons\ of\ CO2e\ per\ passenger\ mile$$

Calculation 1a.

$$115g\ per\ passenger\ per\ km \times \frac{1\ mile}{1.609\ km} = 71.47g\ per\ passenger\ per\ mile$$

$$71.47g\ per\ passenger\ per\ mile \times \frac{1\ metric\ ton}{10^{6}g} =$$

$$7.147 \times 10^{-5}\ metric\ tons\ per\ passenger\ per\ mile$$

Calculation 1b.

$$177\ grams\ of\ CO2e\ per\ passenger\ per\ mile \times 10^{-6}\ \frac{metric\ tons}{grams} =$$

$$1.77 \times 10^{-4}\ metric\ tons\ of\ CO2e\ per\ person\ per\ mile$$

Calculation 1c.

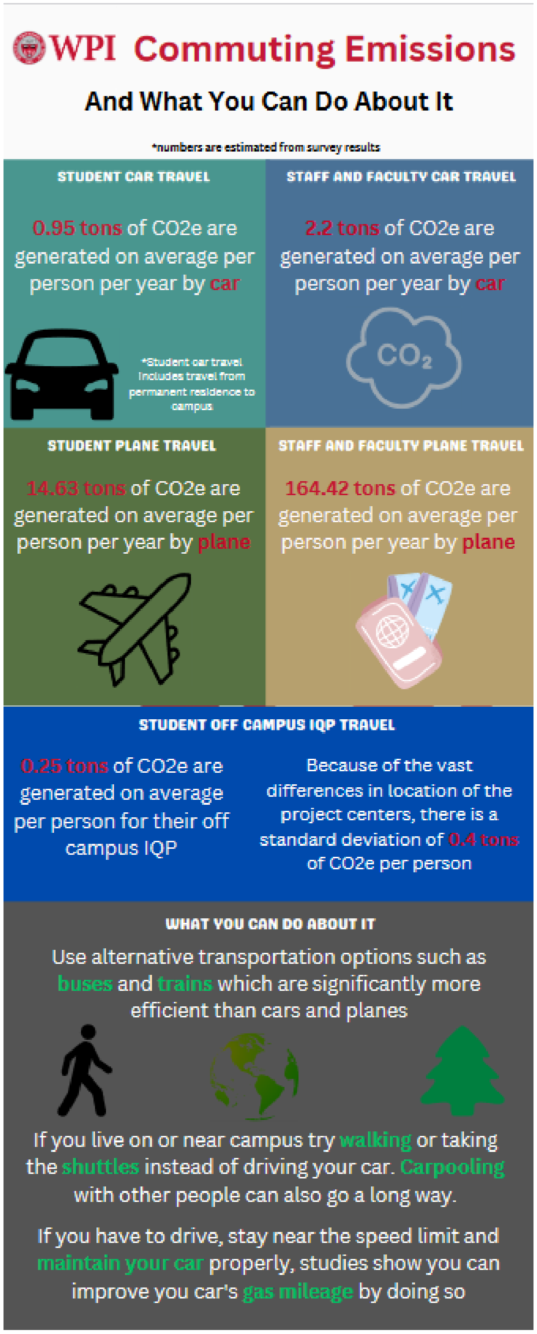
$$299\ grams\ of\ CO2e\ per\ passenger\ mile \times \frac{1\ metric\ ton}{10^{6}\ grams} =$$

$$2.99 \times 10^{-4}\ metric\ tons\ of\ CO2e\ per\ passenger\ mile$$

Calculation 1d.

Appendix B: Deliverables

Student Flier



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