PROJECT REPORT

Designing a Climate Program for the Puerto Rico Project Center

Allyson Floria, Tara Haymon, Cameron Huneke, Martin Wadzinski

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Project Advisors:
Prof. Scott Jiusto
Prof. Gbetonmasse Somasse

Project Sponsors:
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Abstract

The climate crisis is a global issue catalyzed by a steady increase in atmospheric levels of greenhouse gases. This project focused on strategies to analyze and mitigate carbon emissions generated by WPI's Global Projects. To achieve this, we estimated the carbon emissions produced on IQP using the Puerto Rico Project Center as a case study, researched and compared carbon offset companies, and spoke to our stakeholders to generate the most effective guide and outreach methods. This work resulted in calculator tools that can be used to estimate IQP emissions, a roadmap of recommended steps towards carbon neutrality and sustainability, and a website to host our information and generate ongoing discussion around the climate crisis and sustainability initiatives.

Acknowledgements

We would like to express our gratitude to all the groups and individuals that supported us through this project experience. Firstly, we would like to thank our sponsors Puerto Rico Project Center directors John Michael Davis and Scott Jiusto, and the Director of WPI's Office of Sustainability Paul Mathisen. Your trust in us to complete such a valuable project with direct ties to WPI means a lot to us, and we could not have accomplished what we did without your support.

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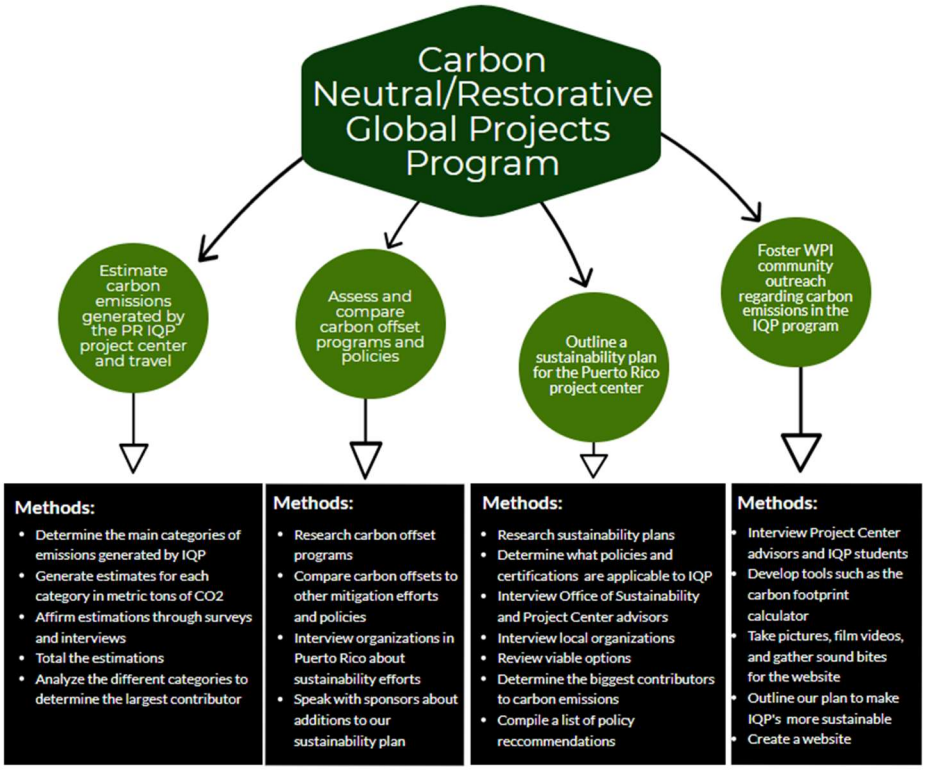
Executive Summary

The climate crisis is a global issue that is impacting the environment and communities in a wide variety of ways (IPCC, 2018). This crisis is associated with the rising of atmospheric temperature due to the increase of concentrated greenhouse gases, specifically carbon dioxide (CO_2). Rising levels of CO_2 trap the sun's heat causing an increase in global temperature and more extreme weather events (USGCRP, 2018), with life altering or even catastrophic effects in many areas (CRS Insight,2018). In Puerto Rico specifically, this is seen in the frequency of hurricanes and tropical storms that leave the island vulnerable to food shortages, loss of water security, health problems, and many other adverse effects (Taylor, et al., 2018). While this project's focus is strongly geared towards Puerto Rico, it is also designed to be applicable to all WPI project centers.

Mission, Objectives, and Methods

This project is intended to aid the Puerto Rico project center to create a more sustainable model for the IQP program by analyzing carbon emissions, exploring offset applications, and moving toward being carbon neutral and ultimately carbon restorative. This model would lay the foundation for future emissions standards at IQP centers. The objectives and methods to pursue to meet these goals are outlined in the figure below.



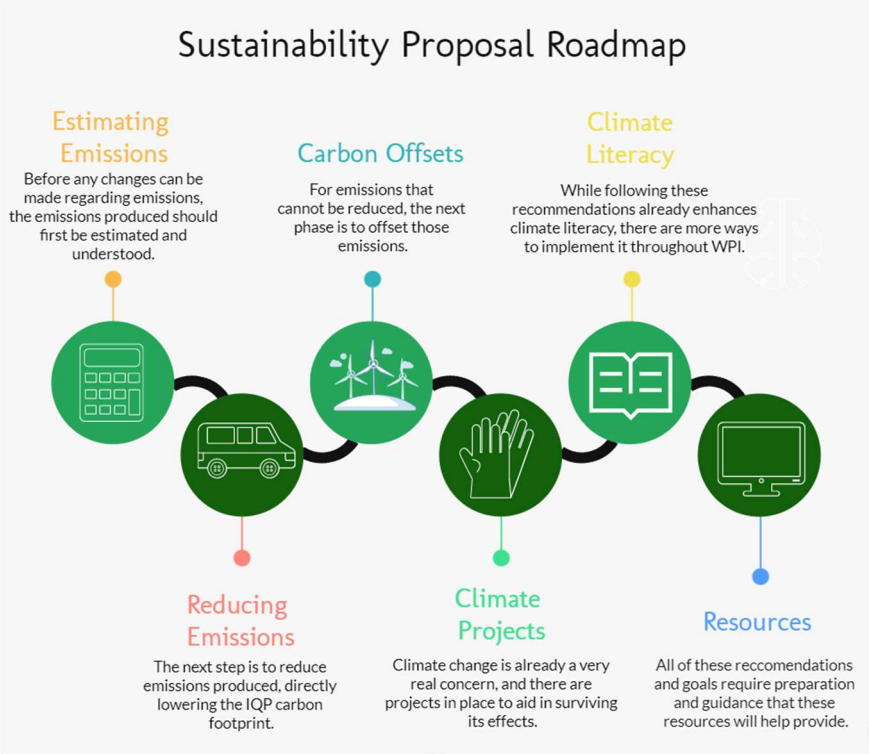
Outcomes and Recommendations

Over the course of this project, several outcomes and deliverables were developed for the Puerto Rico Project Center, Global Projects Program, and the WPI student body. The outcomes are as listed – a sustainability proposal roadmap, PRPC case study, emissions calculators, and a website.

Sustainability Proposal Roadmap

The Sustainability Proposal Roadmap presents a recommended action plan for working towards a more sustainable IQP experience. Within each of the 5 sections, which are Estimating Emissions, Reducing Emissions, Carbon Offsets, Climate Projects, and Climate Literacy, specific recommendations are made based on the findings gathered over the course of this project. There is also a collection of resources after the roadmap that are publicly available and can be used to help carry out the recommendations.

The goal of this roadmap is to offer a series of options, and a path to follow in implementing them, rather than a concrete set of policy recommendations. This should help in the application of the recommendations, as each project site is different and therefore has different needs when it comes to enacting potential policies like those mentioned in the roadmap. This approach allows for more flexibility in the deployment of any recommendations that are used.



PRPC Case Study

The PRPC Carbon Emissions Case Study was conducted by the team to make a gross estimate and assess the breakdown of the carbon emissions produced over the course of the term by the cohorts (Cape Town and Albania) conducting IQP at the PRPC. This case study approximates total PRPC IQP emissions as the sum of air travel, living accommodations, and ground travel estimates. In summary, the case study found that the average flight one-way to Puerto Rico produced 501kg of CO_2, about 320kg of CO_2 for one person's hotel stay, and on average 62kg of CO_2 for their use of ground travel, totaling 883kg of CO_2 per person. According to WPI's 2020 Sustainability Report, an average student produces about three tons of CO_2 per year, or about 650kg in a term. Based on this, a student spending a term at the Puerto Rico Project Center produces about 35% more CO_2.

Emissions Calculators

Two calculator tools were developed to provide a rough estimate of the emissions generated by various aspects of the IQP program. The PRPC IQP Carbon Emissions Calculator is a tool developed specifically for the Puerto Rico Project Center that uses student input to calculate an individualized estimate of the carbon emissions produced by their trip. The IQP Cohort Air Travel Emissions Calculator is a tool developed for all IQP Center Directors and Advisors to easily estimate air travel emissions generated by a cohort travelling to and from their Project Center. The goal of these tools is to raise awareness and promote discussion on the topic of IQP emissions.

Website

A website was created to act as a hub to hold all the project information and outcomes. This website allows readers a briefer version of the information seen in the report and is also a much more efficient way to spread the information through campus more readily. Visit our website for more: https://wp.wpi.edu/gppsustainabilityproposal/

Chapter 1: Introduction

One of the greatest threats that humanity faces today is the climate crisis. It is a global issue caused by an increase in atmospheric concentrations of greenhouse gases, primarily carbon dioxide. Elevated levels of carbon dioxide trap heat from the sun close to the earth's surface resulting in a net increase in global temperatures (USGCRP, 2018). This increase in temperatures and the associated complications have a significant adverse effect on the territory of Puerto Rico. Climate change and an increase in natural variability are projected to worsen the effects of extreme weather. Located in the path of many tropical storms and hurricanes, this is a problem that Puerto Rico is especially vulnerable to (Environmental Defense Fund, 2021). A continuation of current climate change trends will also see a decline in the island's food and water security and an increase in adverse health effects. Puerto Rico's small island geography limits the resources and adaptive capability it has available to respond to these challenges (Taylor, M. A. et. al., 2018). Global travel and tourism are significant sources of carbon emissions, thus amplifying climate change and its effect on the world.

A large staple of Worcester Polytechnic Institute is their Global Projects Program, especially the Interactive Qualifying Project (IQP) experience. While on IQP, students can travel abroad, experience new cultures, and work closely with sponsors and the surrounding communities to make meaningful impacts. Many of these programs focus on making an impact regarding climate change and sustainability, as well as resilience to the events caused by climate change. While these projects do make a substantial impact, we are forced to wonder if they cannot make an even bigger difference.

Outside of the direct work done for IQP projects, students are traveling and participating in similar actions as tourists. Because of the combination of air travel, use of ground transportation such as Uber, and the emissions produced by the hotel that houses students in Puerto Rico, large quantities of greenhouse gases are produced before the project even has a chance to make a positive impact. If there is an abundance of emissions produced before the project begins or during the project, the efforts of the project itself will be towards offsetting those emissions, causing a net zero of emissions. A net zero of emissions may sound like an ideal situation, however, for a program that strives to aid in greater change, this initial mitigation would be best suited to occur separate from the projects.

Many higher education institutions that are working to reduce impacts on climate are focusing their efforts on carbon emissions and carbon neutrality. The Association for the Advancement of Sustainability in Higher Education (AASHE) is an organization that promotes sustainability amongst higher education institutions. AASHE's main program for increasing sustainability in higher education is the Sustainability, Tracking, Assessment, & Rating System (STARS), which is a service where universities can report their sustainability initiatives and receive ratings based on their actions. Schools,

such as the University of New Hampshire, the University of California, Davis, and Tufts University are working on tracking emissions and finding ways to offset these emissions (STARS). The University of Virginia has a sustainable travel program that includes a pledge to offset all sponsored travel (UVA International Studies Office, 2021) while Duke University has a Carbon Offset Initiative Program which works to develop effective carbon offset projects for the school (Duke Office of Sustainability, 2021). Middlebury College has made headway in becoming carbon neutral in 2016 and utilizing various carbon offset and emissions reduction strategies (AASHE, 2017).

At WPI there is a strong push towards being sustainable through not only IQP programs, but even closer to home with the Global Experience Office and the Office of Sustainability on campus. WPI has put lots of work into its sustainability programs and initiatives, and much of this progress has come from past IQPs. The framework for both WPI's Sustainability Plans (Serra, 2008) and Sustainability Reports (Alden, et. al., 2010) were outlined in IQP projects, and the school has continued to sponsor projects that advance its own sustainability. Amongst these projects is one which created an energy tracking dashboard to keep track of the energy usage across WPI's entire campus and present it in a manageable format (Mancinelli, 2018). Another project sought to reduce the amount of food waste WPI sent to landfills and began on-campus composting initiatives (Kelty, 2017). Despite all that WPI has done for its campus operations, they have not yet put together a plan to mitigate emissions caused by travel for their global projects. Few schools have offset programs, and those that do not have well-detailed plans, meaning that one will have to be developed nearly from the ground up to meet WPI's unique global project program. Additionally, the Puerto Rico Project Center ideally wishes to be carbon restorative. However, plans that already exist are mostly just offsets focusing on carbon neutrality and do not move towards restoring previous emissions. Finally, carbon offsets can be somewhat of a controversial issue and are often seen as just a buzzword. In many places, there is a lack of clarity or a concise explanation of carbon offsets, leading to little faith behind these programs.

While higher education is indeed working to reduce its carbon footprint, there are only a few developed programs in existence. Much work still needs to be done, and there are numerous questions that still need to be answered regarding the best methods to reduce one's carbon footprint. Further research is required to understand how effective carbon offsets and other methods of combating carbon emissions really are. For example, weighing the various strengths and weaknesses of resiliency and adaptation compared to that of mitigation is necessary for determining how sustainability-related problems can be solved. More specifically for the Puerto Rico Project Center, understanding how the communities in both Puerto Rico and at WPI view carbon offsets and other measures for reducing carbon emissions will give clarity on any positive or negative feelings toward these topics. Additionally, the actual carbon emissions produced by the Puerto Rico Project Center have yet to be estimated, leaving a

gap in the knowledge of the Project Center's climate impact, and the policies that could be put in place have yet to be determined.

This project is intended to aid the Puerto Rico project center to create a more sustainable model for the IQP program by analyzing carbon emissions, exploring offset applications, and moving toward being carbon neutral and ultimately carbon restorative. This model would lay the foundation for future emissions standards at IQP centers and within the Global Projects Program. In order to achieve this overarching project goal, the team will first estimate the carbon emissions generated by the IQP project center and travel. Next, the team will assess and compare carbon offset programs and then outline a sustainability plan for the Puerto Rico Project Center using the information collected on carbon emission and offsets. Finally, the team will work to foster WPI community outreach regarding carbon emissions in IQP travel.

Chapter 2: Background

The Cape Town Project Center and the Puerto Rico Project Center are two examples of IQP project centers that focus on climate change due to the considerable effects that both Cape Town, South Africa and Puerto Rico face as the climate becomes increasingly erratic and extreme. While these projects often focus on the climate issues and impacts within the communities they work with, it is also important that the project centers look inwardly and ensure that they are acting sustainably when executing the IQP.

In order to successfully develop a climate program for the Puerto Rico Project Center, and potentially extend to future project centers, the team researched climate change and the ways carbon emissions act as a contributor. Research regarding the impacts Puerto Rico is facing with climate change was also a focus since the climate program created would need to be compatible with and address the climate issues surrounding Puerto Rico and WPI's travel and presence in Puerto Rico. Carbon offset programs were additional a necessary focus in the background research since they could be used to offset emissions caused by WPI travel. Weighing the pros and cons of carbon offsets and potentially instituting a carbon offset program may be crucial in developing an ideal climate program. Finally, research was conducted to determine what universities, such as WPI, and organizations have done to develop more sustainable travel abroad programs. With this research, an effective climate program for the Puerto Rico Project Center will be produced.

2.1 Greenhouse Gases and Climate Change

To preface, the energy supplied to Earth's climate system originates almost entirely from the sun (USGCRP, 2018). Therefore, the earth's average temperature change can be simply modeled as the

energy from the sun entering Earth's system minus the amount of energy that the planet dissipates into space. In an equilibrium system, the amount of energy entering the system will equal the amount exiting.

Greenhouse gases such as carbon dioxide and water vapor trap heat close to the surface of the earth. This effect provides a warm and stable climate near the surface of the Earth, "making it possible for life as we know it" (ACS, 2021). Without greenhouse gases, near to surface temperatures are estimated to be 60°F colder than average (USGCRP, 2018). However, elevated levels of greenhouse gases will trap more heat in the atmosphere, reducing the amount of heat the earth can dissipate into space. With more energy entering the system than exiting, global temperatures gradually increase.

Figure 1: GHG Flowchart

Most notably over the past seventy years, human activity and industry have caused a steady increase in atmospheric levels of carbon dioxide. While some greenhouse gases such as water vapor easily precipitate out of the atmosphere, carbon dioxide will stay in the atmosphere until removed (USGCRP, 2018). Processes such as photosynthesis do reduce atmospheric carbon dioxide levels. However, this reduction is proportional to the amount of plant life present on earth and will not automatically compensate for an increase in atmospheric carbon dioxide. Therefore, excess carbon dioxide from human emissions accumulates in the atmosphere and results in the greenhouse effect and gradual warming of the planet.

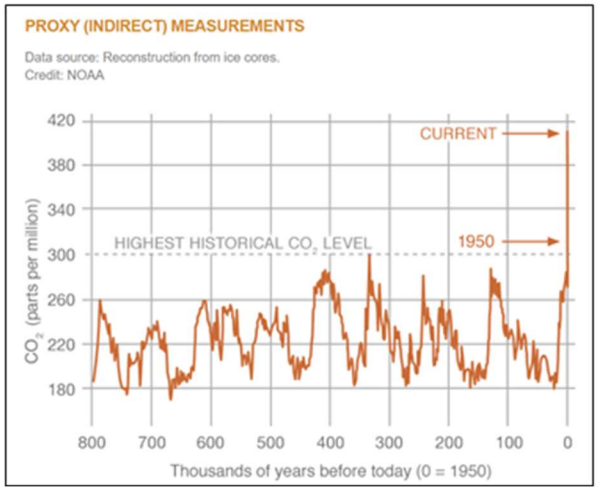


Figure 2: Diagram of historical carbon emissions

(NASA, 2021)

Figure 2 shows the atmospheric carbon dioxide levels of the last 800,000 years. Carbon dioxide levels after 1950 steadily increased well over the previous highest historical CO_2 levels (NASA, 2021). Climate change encompasses the resulting environmental responses elicited by this temperature change. Increasing volatility of extreme weather events, rising sea levels, and the increasing variability of weather patterns and daily temperatures are all examples of the effects of climate change.

2.2 Effects of Climate Change on Puerto Rico

The commonwealth of Puerto Rico is especially vulnerable to the effects of climate change. Many of these vulnerabilities stem from the island's geography and location. Situated in the Caribbean, Puerto Rico is exposed to extreme weather events, is vulnerable to drought, and experiences high average temperatures. These conditions are exacerbated by the effects of climate change and place a strain on the communities of Puerto Rico. (Taylor, 2018)

2.2.1 Island Geography

Puerto Rico's small island geography makes it especially vulnerable to the effects of climate change. As an island in the Caribbean, it is faced with exposure to extreme weather. In addition, the relatively small size of Puerto Rico limits the resources and adaptive capability available to combat this and other effects of climate change (Fain, 2020).

Island geography leaves Puerto Rico exposed to extreme weather. In the fall of 2017, hurricanes Irma and Maria devastated the island, leaving many communities without power or clean water for months. These storms create a negative feedback loop where the loss and damage caused by each storm weakens Puerto Rico's "ability to adapt and respond to future challenges" (Fain, 2020). Climate change has been identified as a contributing factor to these extreme weather systems. Tropical storms and hurricanes are given momentum from the water vapor and heat they receive from the ocean before making landfall. As the oceans warm, tropical storm systems are provided with more fuel. Also, increasing global temperatures and higher evaporation rates lead to higher atmospheric moisture levels (Environmental Defense Fund, 2021). This results in an increase in the intensity of precipitation. As climate change and variability continues to worsen, so too will the danger of extreme weather that Puerto Rican communities are faced with.

Climate projection models indicate increases in mean temperatures, dryness, and instances of extreme weather will cause decline in Puerto Rican agricultural and water potential (Fain, 2020). These changes pose a significant threat to Puerto Rico's food and water security. A decline in agricultural production on the island will increase Puerto Rico's dependency on food imports. While the majority of Puerto Rico's food is already imported from the mainland United States, increasing this dependency will weaken the island's ability to provide for itself, heightening vulnerability to "the effects of climatic

variability, unexpected world events, and other external factors" (Gould et. al., 2015, 38). Drying trends in Puerto Rico are projected to decrease the frequency of precipitation, amplifying the likelihood of drought. Puerto Rico depends on consistent precipitation to supply their communities and businesses with water. In the years 1994, 1995, and 2015, severe drought in Puerto Rico forced the government to impose restrictions that rationed the island's water (Gould et. al., 2015). As climate change trends continue, these problems will continue to worsen.

2.2.2 Increasing Temperatures and Health

Radiative forcing caused by greenhouse gases is responsible for a net increase in the average temperatures experienced in Puerto Rico. As of 2017, the increase in average temperature in Puerto Rico was measured at 1 degree Celsius since the mid-20th century (USEPA, 2016). Climate change also introduces higher variability in day-to-day temperatures. According to the State of the Climate Special Report, Puerto Rico experienced the same number of days at or above 32.2 °C (90 °F) in 2010–2011 as it had per decade from 1900 to 1949 (PRCCC, 2013). In the coming years, climate models indicate an increase in the frequency, intensity, and length of these heat episodes (Lázaro et.al., 2018).

Elevated temperatures have an adverse effect on public health. Research indicates a correlation between elevated temperatures and mortality rates. Heat stroke is a direct result of extended exposure to high temperature. However, higher temperatures can also amplify underlying conditions. The underlying conditions with the strongest association have been identified as cardiovascular disease and stroke (Lázaro et.al., 2018). These effects are exacerbated in cities by the urban heat island effect.

2.2.3 1.5 to Stay Alive

Puerto Rico is disproportionally affected by the climate crisis due to its geographic location. It is almost certain that the trends of increasing heat episodes, resource scarcity, and extreme weather will continue to worsen through the 21st century (IPCC, 2018). However, the severity of these trends will be dictated by the rate at which climate change occurs. For this reason, CARICOM, an organization representing Caribbean communities, is calling to set the goal of limiting human impact on global increase in temperature to 1.5 degrees Celsius above pre-industrial levels through the year 2100 (CARICOM, 2018).

The phrase "1.5 to stay alive" describes the stark reality that survival may be the best-case scenario. Climate models indicate that even the 1.5 °C scenario will significantly increase the climate related risks for "disadvantaged and vulnerable populations through food insecurity, higher food prices, income losses, lost livelihood opportunities, adverse health impacts and population displacements" (IPCC, 2018). As of 2015, the mean global temperature has already increased to 1 degree Celsius above preindustrial levels. If emissions continue at their current levels, global temperatures are expected to reach

1.5 °C between 2030 and 2052 and 3.0 °C by 2100 (CARICOM, 2018). Aggressive and immediate action will need to be taken to limit the increase in mean temperature.

2.3 Travel and Climate Change

Tourism is a major source of income for many communities; however, it is also a source of carbon emissions. This creates a double-edged sword as eliminating tourism would lead to a drop in the economy of these communities, while continuing tourism will keep the industry's carbon footprint growing. While many may say that simply not flying will eliminate this massive carbon footprint, it has been observed that air transportation only accounts for about half of the total carbon footprint of tourism (Sustainable Travel International, 2020). The other half comes from the activities that tourists take part in once at the location of their travel (Sustainable Travel International, 2020). This goes to show that eliminating air travel would not eliminate the emissions produced by tourism. While this is only a snapshot of data, it sparks interesting discussion around the idea of sustainable tourism and how that can be achieved.

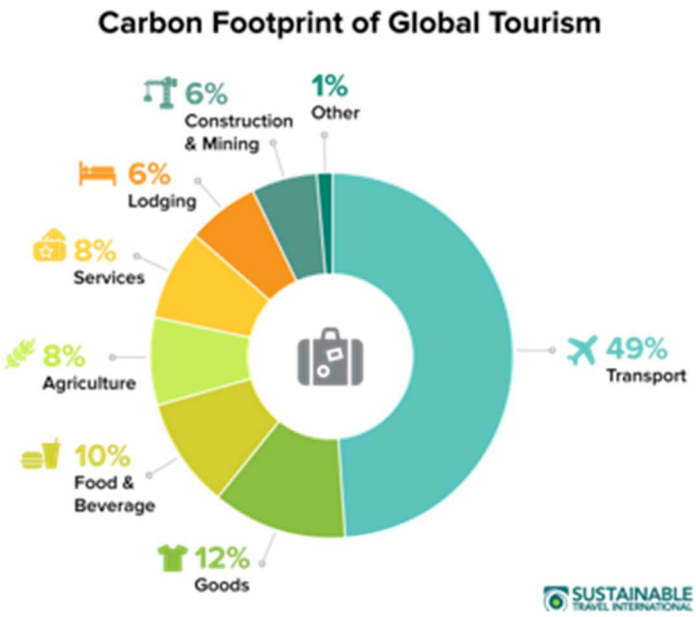


Figure 3: Breakdown of the carbon footprint of global tourism

(Sustainable Travel International, 2020)

Emissions caused by air travel are a focus for universities when looking at developing more sustainable study abroad programs. The travel required to get students to and from their destination for a travel abroad program is often the main contributor to carbon emissions, so many schools start here. Figure 3 outlines the estimated carbon emissions by region for students traveling to/from the US on undergraduate educational travel programs.

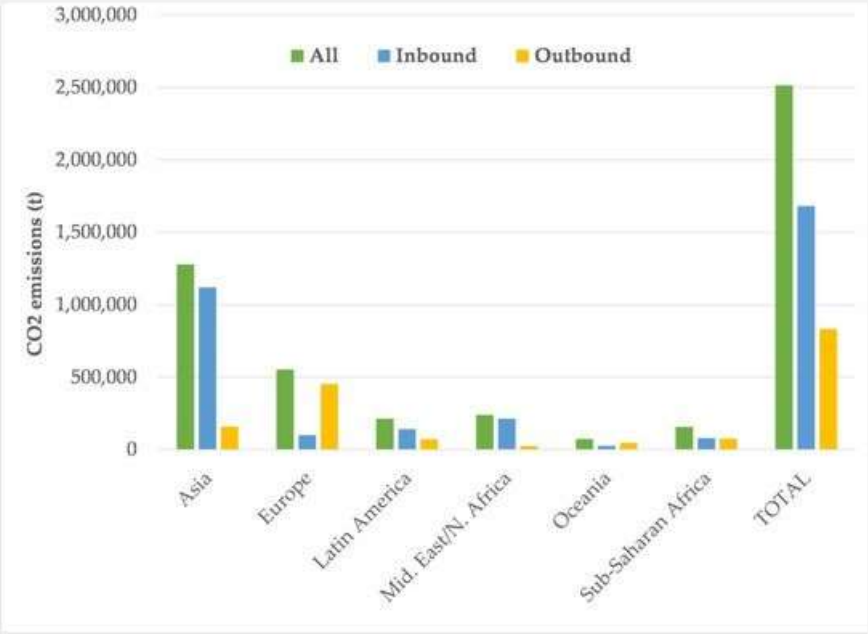


Figure 4: Estimated carbon emissions by region for students traveling abroad

(Hale, B. W., 2019)

In addition to the emissions generated by air travel, students will generate a carbon footprint while at their travel abroad destination through accommodations, ground transportation, and other actions taken. These emissions will ultimately lead to a negative impact on the climate, which often goes against universities' goals for sustainability.

2.3.1 Hotel Emissions

With hotels and tourism contributing to 5% of the global emissions of CO2, it is also fair to note that in many places, tourism is one of the largest economic beneficiaries. This is especially true in Spain, where tourism is one of the two largest sectors of the economy. With this kind of paradox, the hotel sector requires more in-depth evaluation. A case study of hotels in Spain examined the difference in services, waste, and overall carbon footprints of 14 different hotels ranging from two to five stars. After gathering and analyzing the energy, water, and waste consumptions, an average for each star-rated hotel was created and the CO2 production average of each was estimated.

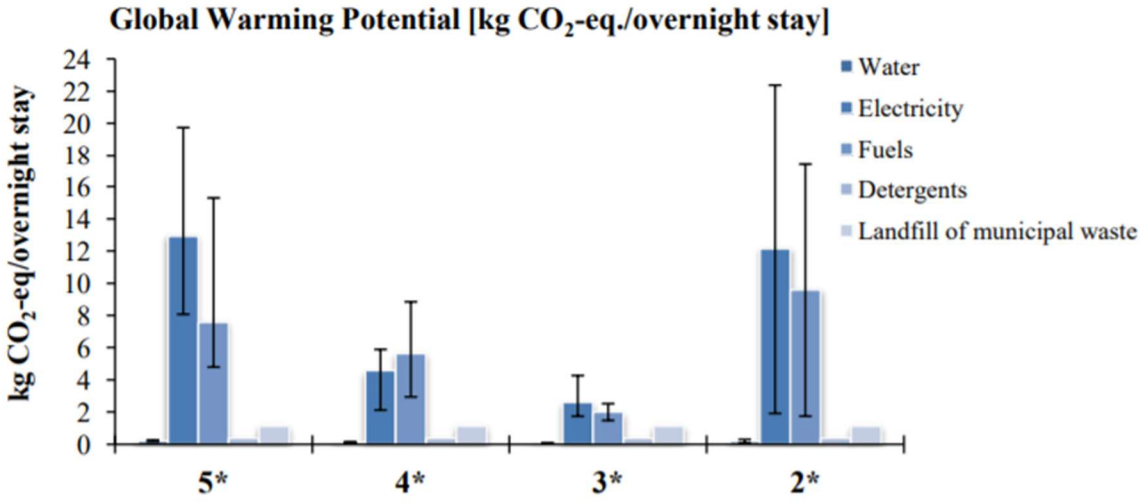


Figure 5: Contribution of primary consumptions to overall hotel carbon footprint

(Puig, 2017)

The findings of this study were quite interesting to examine. As seen in figure 5, which shows the average CO2 per overnight stay in kg for each star rating, the highest contributions to the hotel's carbon footprints in every rating were energy and fuel, with water usage only accounting for about 1% of emissions. Beyond that, it can be noted that the overall CO2 production was highest at the 2-star and 5-star hotels and substantially smaller at the 3-star and 4-star. At the Puerto Rico Project Center, the living accommodations are a hotel with a 3-star ranking; therefore, based on this study, should have a lower carbon footprint than some other hotels in the range of 2-stars or 5-stars. (Puig, et. al., 2017)

2.3.2 Sustainable Travel

One of the easiest ways to reduce carbon emissions caused by travel is to simply limit travel when possible. With aims to increase sustainability as well as dealing with the emergence of the COVID-19 Pandemic, many schools are moving to virtual space for global programs. However, travel abroad has been shown to be beneficial to students in higher education. Studying abroad gives students the opportunity to broaden their understanding of the world, change perspectives, and learn things that would not be possible to learn while on campus (Hale, 2019). Because of this, abandoning travel abroad in order to eliminate emissions caused by travel would likely have a negative effect on the student experience (Hale, 2019).

Many schools, such as WPI, view travel abroad as a valuable and even necessary experience, so abandoning travel is not really an option. The other option then is to create a more sustainable travel experience. The United Nations Environment Programme (UNEP) has defined sustainable travel as the

following: “Sustainable Travel is … defined as Travel where the associated environmental, social, and economic impact is minimized without negatively affecting the ability of the organization to deliver its mandate” (Tripoli, 2010).

One of the primary negative impacts caused by travel abroad programs is an increased carbon footprint. Global travel generates large amounts of carbon emissions, and the impacts of these emissions and the climate crisis especially affect vulnerable populations, which are often the groups travel abroad programs are set out to help (Hale, 2019).

However, these negatives can be combated through a combination of mitigation, adaptation, and resiliency efforts. Some examples of actions that could be taken include critical analysis, research, service projects and volunteering, carbon offsets, choice of destination, mode of travel where applicable, and lodging, meal, and activity choices (Hale, 2019). Collecting data to be aware of one’s self-impact, such as calculating carbon footprint to then purchase carbon offsets, is also a strategy to be a responsible and sustainable traveler.

Figure 6: WPI IQP project center locations

(WPI Undergraduate Studies, 2021)

The IQP program is a significant part of the WPI experience, sending around 80% of students to various project center locations throughout the world. WPI’s IQP program sends students to work with communities to address issues of great importance. Many of these projects share the themes of mitigation, adaptation, and resiliency, addressing “problems related to energy, environment, sustainable development, education, cultural preservation, and technical policy” (WPI IQP website). These projects benefit the communities they take place in and help make said communities and their members more resilient toward a variety of issues they face. Some projects that the Puerto Rico Project Center is working

on that focus strongly on resiliency include waste management, mangrove restoration, and the building of a community center.

However, these IQP trips are also significant sources of greenhouse gas emissions themselves. Emissions from air travel, daily commutes to project sites, and tourist style living add up over the course of a term. The dilemma of IQP travel is not as cut and dry as it may seem. The current model does create significant emissions, but it also provides a unique experience and service to the students and communities it reaches. Therefore, while it would be easier to end travel in the program, if the possibility to reduce the programs carbon emissions exists it should be sought after.

2.4 Carbon Offsets

A growing contribution to the global issue of climate change is the extensive emissions of Greenhouse Gases, specifically Carbon Dioxide (CO2). CO2 emissions are everywhere and are deeply embedded into our normal everyday lives. Every time you drive your car or even use a lot of electricity, you are contributing to the CO2 levels in the atmosphere. This doesn't even begin to cover the emissions of factories and companies that we may work at or buy from, adding to our own carbon footprint. While so many of these emissions have become commonplace, the real question becomes how we can reduce the current CO2 levels, as well as preventing it from continuing to exponentially grow. This is where Carbon Offset programs enter the equation.

Carbon offset programs are plans not to reduce the CO2 emitted, but to instead find ways to pay it back or absorb the CO2 from the atmosphere, essentially "offsetting" the issue that they present (Guardian, 2011). The idea of cancelling out the CO2 we put into the atmosphere may sound like the ideal solution, however, there are many things to consider with these types of plans. It is important to look at this problem and this solution for all sides, of every stakeholder involved.

Companies can sell offsets to individuals who wish to balance out their emissions but don't know how to or have the means to (UNEP, 2019). What this means is that using either their own estimations or a calculation created by someone, an individual will estimate the amount of carbon emissions they have produced for what they wish to offset, this number will be in tons so they can buy that number of offsets from a company. From that point, the company uses the money to fund or support sustainable technology or practices.

2.4.1 Four Types of Offsets

There are four major types of offset programs that can be implemented to mitigate carbon emissions. These methods include forestry and conservation, renewable energy, community projects, and waste to energy (EIC, 2020). Forestry and conservation is a type of carbon offset which is very commonly

used and known. This method is when trees are either planted to equal the credit of produced emissions or when trees are protected to maintain the flow of carbon and oxygen. Renewable energy is another popular one as this is the use of things such as solar panels and windmills that are used as a cleaner source of energy to eliminate the carbon produced by energy use. Community projects are typically used to increase the technology and energy efficient methods used in underdeveloped communities. Finally, there is the method of waste to energy which is when greenhouse gases and converting that directly into energy, thus eliminating existing waste as well as producing cleaner energy. These kinds of projects are most seen with the use of methane gas though can also include carbon emissions as well.

2.4.2 Public Perceptions

In terms of the public view, there are a lot of mixed feelings towards offset programs and a lot of different responses from individuals and communities. The very first thing to investigate in this regard, is wiliness to participate in the programs. While carbon offset programs can be highly effective, they won't do much of anything without support and participation. In addition to generating support and participation of these programs, making sure that the public is educated about what these programs are is very important. One article (Günther, 2020) investigated the behavioral responses of individuals who partook in offset programs noting that the response is unclear, however, that many who contribute to carbon offsets are more likely to partake in high emission activities in the future, when in truth, the offsets are for previous emissions. Additionally, some may feel that the issue of the carbon emissions of that specific product is no longer a prominent issue, as they themselves will not have to deal directly with the future or attached consequences.

2.4.3 Other Mitigation Efforts

Another mitigation effort like carbon offsets is carbon sequestration. Much like the process of waste to energy, carbon sequestration is a method where carbon dioxide is directly removed from the atmosphere. (USGS, n.d.) However, in sequestration the CO2 is then stored away. In many cases, CO2 is stored deep underground in a type of sequestration known as geologic sequestration. There is a second method, known as biological sequestration, in which the natural ecosystems that remove CO2 are enhanced with slight human modification of support to capture CO2 more effectively.

In addition to looking at carbon offset programs and carbon sequestration, carbon sinks are another method of decreasing carbon levels and stopping them from rising too quickly. “A carbon sink is anything that absorbs more carbon dioxide from the atmosphere than it releases.” (Fern, 2016) While carbon sinks are seen as a “negative emission” it is still especially important to note that they do not delay or rid the bigger issue at hand. This is largely because the carbon dioxide absorbed by trees is moving

continuously through a cycle of oxygen and carbon dioxide, whereas carbon stored in fossil fuel is stagnant and cannot be canceled out by these sinks and offsets.

2.5 Universities and Sustainable Travel Initiatives

As the world's climate crisis becomes more and more apparent, an increasing number of institutions are implementing sustainability practices to lessen their impact on the environment. Many of these programs being created are still in their infancy, but they are nonetheless a promising step toward developing environmentally friendly travel for higher education. Most have started their approach with recording emissions to be offset; however, clear, concise ways to offset said emissions have not yet been developed. The following section will highlight a few of the many institutions working toward sustainable travel, which will ultimately be used as a guide for the development of the climate program for the Puerto Rico Project Center.

2.5.1 STARS & AASHE

One resource for collecting information on university sustainability efforts is the Sustainability, Tracking, Assessment & Rating System (STARS). This system was created by the Association for the Advancement of Sustainability in Higher Education (AASHE) as a way for universities to report on their endeavors to be more sustainable. Universities receive Platinum, Gold, Silver, or Bronze ratings based on sustainable efforts and participation in STARS.

2.5.2 University of Virginia

In February of 2020, UVA's International Studies Office collaborated with the Office of Sustainability to develop a sustainability plan for travel abroad. This plan contains initiatives that focus on several factors affecting the sustainability of a travel abroad program. These initiatives include the following:

- Offsetting all carbon emissions of air travel for education abroad programs administered and managed directly by the ISO
- Offsetting all carbon emissions for all ISO/SUMS staff travel
- Making flight emissions information accessible on education abroad program budget sheets
- Working towards completing UVA's Green Workplace Program
- Committing to 100% zero-waste and carbon neutral events
- Prioritizing sustainable accommodation options where possible and cost-effective when making lodging arrangements for education abroad programs
- Integrating sustainability into every aspect of its operation and programs and expanding its offering of available resources for students, faculty, and staff

- Developing and expanding existing partnerships with UVA's Office of Sustainability and William and Mary
- Exploring partnerships with and support for local forestry or sustainability projects.

(UVA International Studies Office, 2021)

One concrete solution that UVA's International Studies Office plans to move forward with is the purchasing of carbon offsets to offset the emissions produced by air travel. In 2019, a total of 2,720 metric tons of carbon emissions was created by UVA travel abroad programs, with the average carbon footprint of a UVA traveler being around 2.02 metric tons (Figure 5). According to UVA, that 2.02 metric ton footprint translates to about $15.88 in carbon offsets per UVA traveler (Figure 5). The UVA International Studies Office has pledged to pay this price for carbon offsets for all UVA-sponsored travel going forward.

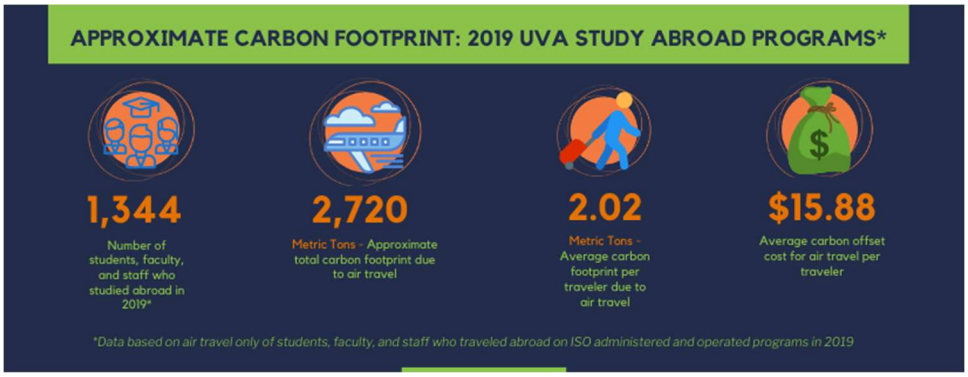


Figure 7: Emissions data from International Studies Office administered programs in 2019

(University of Virginia International Studies Office, 2021)

2.5.3 Duke University

Duke University created the Duke Carbon Offsets Initiative (DCOI) in 2009 with the goal to become carbon neutral (Duke Office of Sustainability, 2020). Duke is a member of the Offset Network, which has the following mission statement: "To facilitate and catalyze high-integrity, unique offset projects that provide educational and research opportunities for students, faculty, and staff by connecting peer institutions and aggregating best practices" (Duke Office of Sustainability, 2021). Through this initiative, Duke University has gathered data and worked with numerous offset programs to determine which are the best ways to offset their carbon emissions.

One project that Duke University developed is the Urban Forestry Carbon Offset Protocol, which outlines the method for "determining carbon dioxide equivalent storage associated with urban tree plantings" (Duke Office of Sustainability, 2021). This is a form of sequestration as well as a carbon sink whereby Duke University – through their DCOI Urban Tree Planting Program – strategically plants trees

in urban areas to offset carbon dioxide emissions. The trees would absorb the high levels of carbon dioxide in these urban areas, and provide other environmental benefits, such as pollination, erosion protection, urban heat reduction from shade, and decreased water and air pollution (Duke Office of Sustainability, 2021). To create a credible and beneficial plan, Duke University based much of their plan off of guidelines listed in the Climate Action Reserve's Urban Tree Planting Project Protocol (Duke Office of Sustainability, 2021).

Duke University additionally works with Loyd Ray Farms, which is a waste-to-energy farm that converts methane emissions caused by livestock waste into electricity (Duke Office of Sustainability, 2021). Another project the DCOI is looking into is working with a local land trust to protect forests near Duke from development to stop a major carbon footprint before it can be created (Duke Office of Sustainability, 2021).

2.5.4 University of New Hampshire

The University of New Hampshire is one university that is prioritizing mitigation of carbon emissions before carbon offsets. UNH is utilizing the Carbon Management Hierarchy in their Climate Action Plan, which focuses on stopping carbon emissions from being produced in the first place through avoiding actions that create unnecessarily high carbon emissions, reducing emissions produced from unavoidable actions, and replacing sources of high emissions with ones that produced fewer emissions (Andrews, et al., 2021) (Figure 6). UNH is additionally collecting data on travel purchases, distance travel, and mode of travel to determine travel emissions and work toward minimizing said emissions (STARS, 2011).

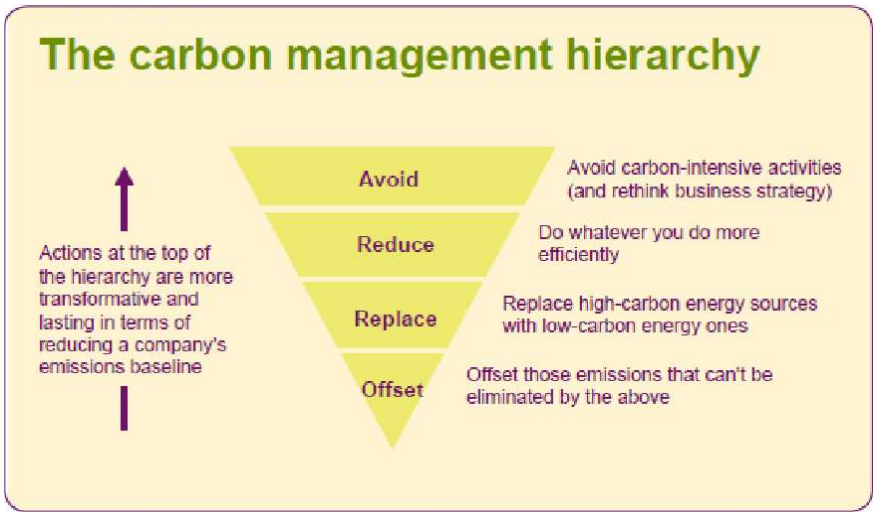


Figure 8: Carbon Management Hierarchy

(Andrews et. al., 2021)

2.5.5 University of California, Davis

The University of California, Davis is an example of a school that plans to limit travel using virtual communication. In their Climate Action Plan, the University of California, Davis has chosen to prioritize telecommunicating where possible by putting funds into technology and facilities for "high-quality remote conferencing" (STARS, 2013). This would ensure that the school would not produce any unnecessary emissions while still being able to effectively complete global project work.

2.5.6 Tufts University

Several universities are additionally employing Green Workspace Programs to improve the sustainability of work environments. For example, Tufts University has outlined a Green Office Certification Program that focuses on the following criteria: Energy & Water Use, Waste & Recycling, Printing & Office Supplies, Food, Beverages, & Dishware, Transportation, and Sustainability Planning and Leadership (Tufts Office of Sustainability, 2020). The goal of the Green Office Program is to make the day-to-day workplace more sustainable and draw attention to how one's workspace might contribute to climate impacts. While this program does not necessarily focus on travel, certain practices, such as turning off lights when not needed, could be implemented into the IQP stay to reduce the carbon footprint caused by day-to-day work and activities.

2.5.7 Middlebury College

Middlebury College has been carbon neutral since 2016 and is an example of a university with comprehensive sustainability initiatives (AASHE, 2017). The campus has a biomass gasification plant that burns woodchips to create energy for heating and cooling purposes (Franklin Environmental Center, 2021). The plant is responsible for generating 15 to 20 percent of the school's electricity, and "switching from fuel to biomass cut Middlebury's carbon footprint by 40 to 50 percent" (Franklin Environmental Center, 2021).

Middlebury College has a conservation program on its Bread Loaf Campus, which has preserved 2100 acres of land (Franklin Environmental Center, 2021). This conservation effort was then assessed by a carbon accounting company, called Blue Source, which "quantified carbon credits based on the amount of carbon dioxide sequestered by the Bread Loaf forests" for the school to offset its remaining carbon footprint (Franklin Environmental Center, 2021).

Renewable energy has also been a primary focus for Middlebury College. The school has a number of solar power initiatives, such as a 143kW solar farm with AllEarth Renewables and a 500kW solar farm with Wilber Solar. The campus additionally has a 10kW wind turbine. Middlebury College has pledged to transition to 100% renewable energy by 2028.

In 2006, Middlebury College created one of the first study abroad carbon offset programs in partnership with a Vermont-based carbon offsets company called Native Energy (Middlebury Study Abroad, 2021). The purchased offsets funded Native Energy projects, including "renewable energy at schools, methane digesters on family farms, household water filters in rural Kenya and even the first large scale Native American-owned wind turbine in the U.S." (Middlebury Study Abroad, 2021). Middlebury College additionally has a Sustainable Study Abroad Grant program, where students can apply for a grant of up to $500 for sustainability focused research projects (Middlebury Study Abroad, 2021).

2.5.8 Race to Zero

The Race to Zero campaign is a global campaign that works to encourage leadership in universities and organizations to support a healthy, resilient, zero carbon future that fosters sustainability growth. With 3067 businesses and 622 higher education institutions signed on, Race to Zero spans over 733 cities and 31 regions. Organizations that sign the pledge to Race to Zero are pledging to work to reach net zero carbon emissions by the year 2050 at the latest.

By joining Race to Zero, organizations have a four-step process: Pledge, Plan, Proceed, and Publish. Beyond what has already been stated, the pledge also includes the agreement to work towards limiting global warming to 1.5 degrees Celsius and set a target goal to achieve in the next decade that shows a strong effort to reach 50% reduction in carbon dioxide by 2030. Following the pledge is the plan. This means that each organization that pledges must, within their first year, explain their short term and long-term plans and goals. After that, they proceed to immediate action towards these goals. Finally, the stage of publishing is the commitment to report their findings and progress at least yearly to the UNFCCC Global Climate Action Portal. (UN Climate Change, 2021)

2.6 WPI's Efforts Towards On-Campus Sustainability

WPI has been focused on improving its sustainability in both its academic programs and campus operations for several years. In 2006, the board of trustees voted that all new buildings going forward would be LEED certified. Since then, East Hall, the Recreation Center, Faraday Hall, the Innovation Studio and Messenger Hall have all received a LEED certification. Additionally, in 2014, WPI released its first "Sustainability Plan," based around the three guiding principles of ecological stewardship, economic security, and social justice. They set out four categories of objectives that they hoped to meet through these principles: academics, campus operations, research and scholarship, and community engagement. The institute also demonstrated its dedication and progress on matters of sustainability through its Sustainability Reports, which are published yearly. One major example of improving campus operations was mentioned above with the LEED certifications on new buildings. However, many of the

institute's other advancements in sustainability have come around as results of other IQPs. Both the Sustainability Plan and Sustainability Report were designed in IQPs, in 2008 and 2010 respectively.

2.6.1 Sustainability Plan and Report

WPI's Sustainability Plan was first outlined in an IQP submitted in 2008, which made a series of recommendations to the WPI President's Task Force on Sustainability, with the intent of improving the new sustainability program. The project made several recommendations, the most significant being the recommendation to invest in a "revolving loan fund." The hope for this fund is that the money taken out is used for sustainability improvements and programs that will save the institute money or provide a significant return on investment. This recommendation was implemented and renamed to the Green Revolving Fund. The project also outlined the development of incentives programs, both competitive and non-competitive programs, as well as promoting sustainability in academics. Most of these incentives were recommended to be awards of some kind. Finally, the project recommended creating a sustainability coordinator to have a dedicated person responsible for managing and facilitating task forces and programs related to advancing sustainability. (Serra, 2008)

In 2010, 2 years after the sustainability plan project was published, another IQP made an outline for a Sustainability Report – something that is common practice among companies but was just starting to become more common for universities at the time. The purpose of the report is to allow WPI to "create a snapshot" (Alden, et. al., 2010, 1) of where they stand on sustainability goals and objectives and discuss the initiatives currently in place and those they wish to implement in the future. The first sustainability report was published in 2010, and WPI has published one yearly since then. The reports have grown in size and scope each year, and now are quite comprehensive regarding WPI's sustainability efforts, initiatives, goals, and policies.

2.6.2 Energy Tracking

Another more recent IQP was a project which set out to monitor and present WPI's energy consumption in a way that was easy to understand and analyze. This project made use of a large network of electricity monitors to record the energy usage of most of the WPI campus and on-campus housing. In addition to gathering this data, the team also created an energy monitoring dashboard with the purpose of making WPI's energy usage more visible and understandable. The project's background research included a study which found that people are more likely to make energy efficient and sustainable choices when they are more aware and energy information is presented in a more visual method. (Mancinelli et. al., 2017)

2.6.3 Food Waste Management

In 2018, an IQP team was tasked with modifying WPI's food waste management process. Food waste is WPI's second largest source of solid waste by weight (WPI Sustainability Report, 2011, 2012, 2014, 2016), so reducing food waste in any way makes a significant impact on WPI's waste footprint. This project recommended adding a composting pilot program to the Rubin Campus Center, because that was where the most post-consumer food waste ended up in the normal trash, as opposed to being diverted to other waste management methods such as composting. The team also wanted to make sure that awareness was raised about the new compost disposal options and came up with several methods to advertise the new pilot, such as a Zero Waste BBQ and new signage. (Kelty et. al., 2018)

Chapter 3: Methodology

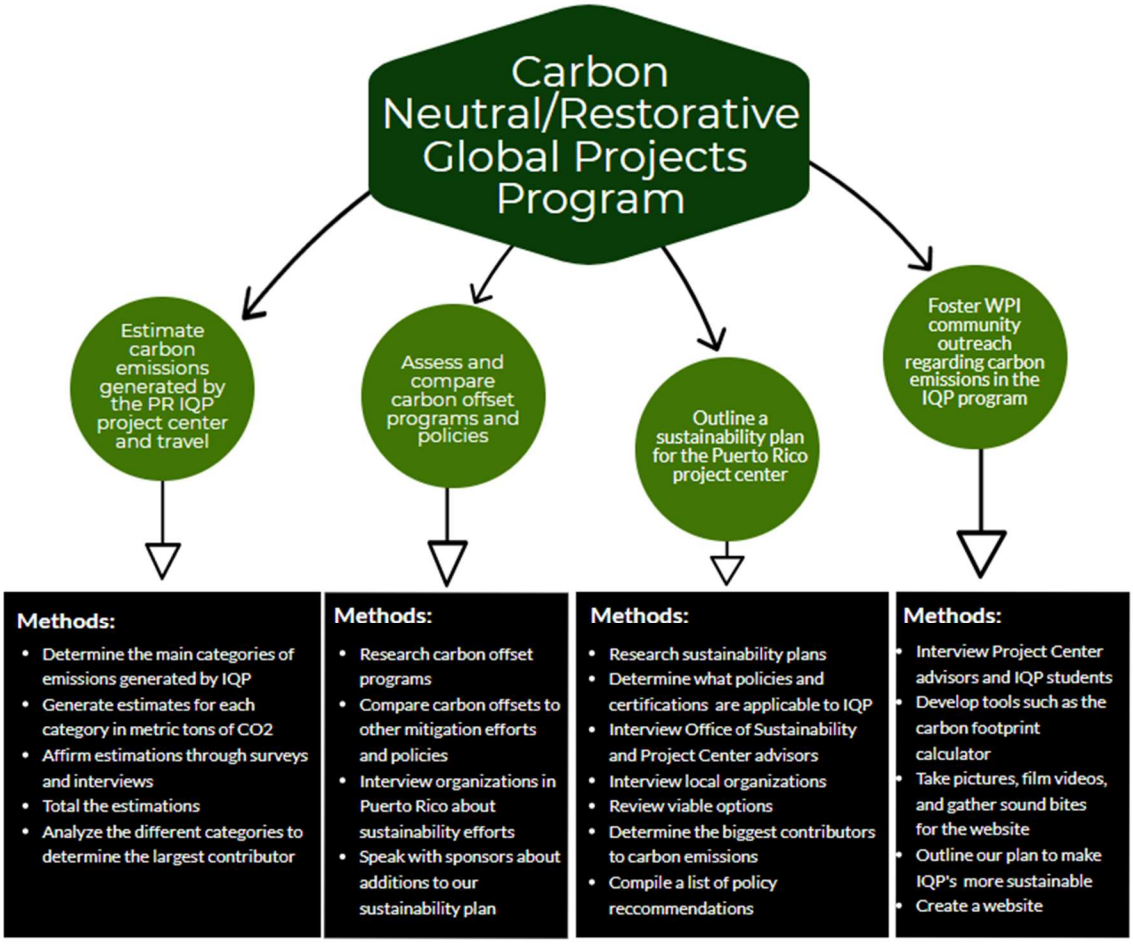


Figure 9: Graphical representation of the project methodology.

Project Goal and Objectives

This project is intended to aid the Puerto Rico project center to create a more sustainable model for the IQP program by analyzing carbon emissions, exploring offset applications, and moving toward being carbon neutral and ultimately carbon restorative. This model lays the foundation for future emissions standards at IQP centers. To achieve these goals, the following objectives were pursued:

1. Estimate carbon emissions generated by the Puerto Rico Project Center and travel
2. Identify the best practices in carbon offsets or other carbon restorative programs
3. Outline a sustainability plan for the Puerto Rico Project Center
4. Foster WPI community outreach regarding carbon emissions in the Global Projects Program

3.1 Estimate Carbon Emissions Generated by the Puerto Rico Project Center and Travel

The first objective was to determine a method to estimate the carbon emissions generated per person during the Puerto Rico IQP Program. The total calculation was split into the subcategories of airline, daily commute, and hotel living. This way, the research and adaptation of existing emissions calculators will supply the team with an accurate estimation for each subcategory. Specific information required for any of these estimations was collected at the Project Center by surveying students. Completion of this objective provided the team with a per person estimation that could be used to calculate the total emissions generated by the project center. It also provided a metric to compare emissions generated from various aspects of the IQP. This allowed for analysis of what areas should be improved on.

3.2 Identify the Best Practices in Carbon Offset or Restorative Programs

The second objective our team tackled is to assess and compare different offset programs and policies that already exist and may be applicable to our project. We continued to educate ourselves on the process of carbon offsetting and compare the various methods used to do so to determine which methods we could pull from. To select the best additions to our plan, it was important to fully understand the programs and policies out there and assess them with our project's specifics in mind. With a full understanding of the logistics regarding carbon offsets, we dove into the programs and policies that are being used by other universities and organizations and decided how relevant those policies are for our purposes. From this, we created a list of policies and programs that would be most effective to implement into our project, as a roadmap of recommendations for the WPI IQP program.

3.3 Outline a Sustainability Plan for The Puerto Rico Project Center

The third objective that we completed was creating a detailed roadmap to be the base of development for a full sustainability plan for WPI's Puerto Rico Project Center. This roadmap provides a list of initiatives and policy options with a focus on mitigation, adaptation, and resiliency that the project center could utilize to become more sustainable and carbon restorative. The roadmap also contains initiatives inspired by actions being taken by other universities and organizations, and some information gathered while the team was in Puerto Rico. Additionally, the measures taken by the Puerto Rico Project Center could act as a model for IQP travel, and the roadmap could be applied to other project centers in the future. By creating this roadmap, we aimed to provide a series of options for reducing the emissions and climate impacts caused by IQP travel and contributing to the sustainability efforts at WPI.

3.4 Foster WPI Community Outreach Regarding Carbon Emissions in the IQP Program

The fourth objective we pursued was the creation of outreach methods to help teach and perpetuate our climate plan. In addition to educating ourselves on the processes of carbon offsetting and gaining an understanding of our carbon impact from travelling for an IQP project, we wanted to be able to pass this knowledge on to future IQP students. We also wanted to impart an idea of what students and project center advisors would be able to do to reduce their emissions or move towards being carbon restorative in the future. The primary way in which we carried this out is through a webpage on the WPI Global Labs website that contains our findings and recommendations roadmap. This website will contain the climate plan produced by this project, as well as multimedia elements of projects and climate initiatives that other students present at the project center took part in. The site also contains the emissions calculator that we developed over the course of the project.

Chapter 4: Sustainability Proposal Roadmap

This chapter presents the Sustainability Proposal Roadmap developed by this project. This roadmap is intended to be used by WPI as a list of ways to improve the sustainability of the Global Projects Program and is organized in a way to reflect a logical order of progression between steps.

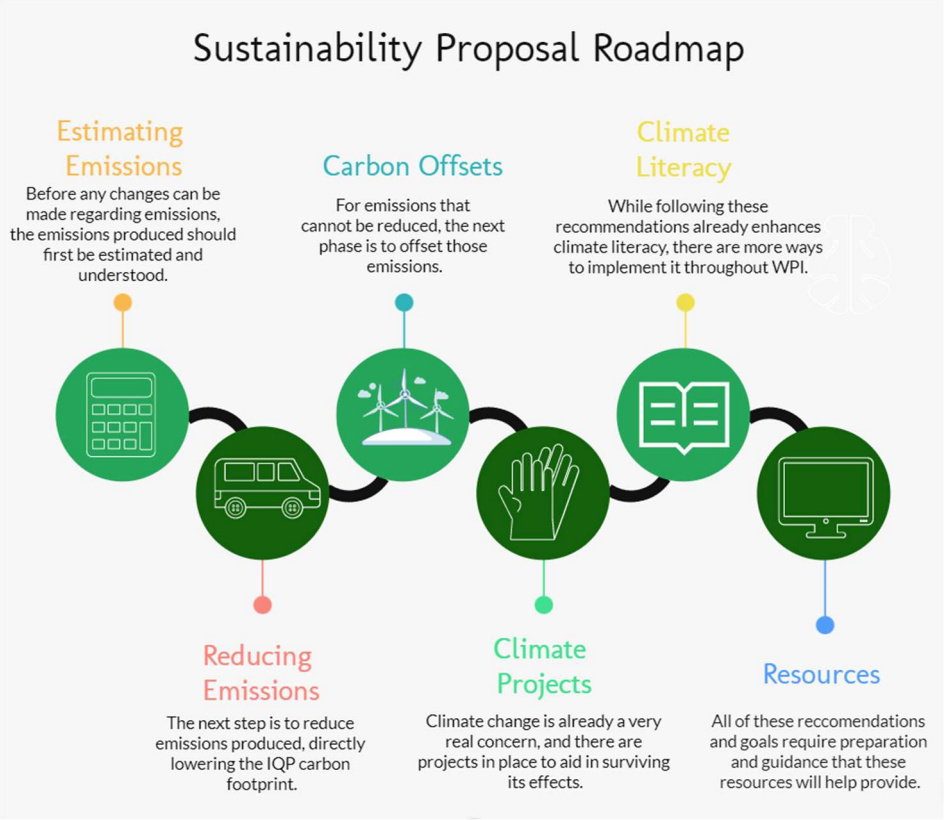


Figure 10: Overview of the sustainability proposal

This roadmap is split into several sections of recommendations. Recommendations are made regarding estimating emissions, reducing emissions, carbon offsets, climate projects, and climate literacy. In each recommendation there is a brief introduction of the goal, followed by the process needed to be completed to achieve that goal. After all recommendations have been given and explained, a resource section will provide links that offer guidance in the process of completing all the objectives laid out in this plan.

Building off the Carbon Management Hierarchy, this proposal additionally acknowledges the need to estimate emissions first, thus understanding what it is that needs to be reduced or offset. This program also recommends going beyond the hierarchy to include growing and improving climate focused projects and climate literacy.

Roadmap Step 1: Estimating Emissions

The first step in the Climate Roadmap is for the carbon emissions generated by each project center to be estimated using a common methodology. It is only when the quantity of emissions produced are estimated and known that strategies for their analysis, reduction, and offset can be developed. There are many organizations that provide institutions with carbon emission calculations, some specifically for universities (AASHE). WPI utilizes such resources, generating campus emissions estimations that facilitate the development of documents such as the sustainability plan (WPI Office of Sustainability, 2020). A logical next step is to extend WPI's estimation methods to include the emissions produced by the Global Projects Program.

As part of this IQP, the team conducted a case study with the PRPC that approximates the emissions produced by the Cape Town and Albania cohorts (diverted to Puerto Rico in 2021 due to COVID) as the sum of emissions estimates for air travel, living accommodations, and ground travel. Based on the methods used in the case study, the team developed two calculators. The first, the PRPC IQP Carbon Emissions Calculator, was developed as a tool for PRPC IQP students that can be used to easily approximate the emissions generated on an individual student's IQP. The second, the IQP Cohort Air Travel Carbon Emissions Calculator, was developed for all Center Directors and Advisors as a simple way to estimate the flight emissions generated by their cohort's IQP air travel. For more information on the case study and calculators see Outcomes.

Below are recommendations for estimating the emissions generated by the GPP. These recommendations fall under two main categories: estimation for the purpose of carbon offsetting (1.1-1.3) and estimation for the purpose of academic discussion (1.4), the distinction being emissions estimates used for carbon offsets should be generated by accredited organizations while estimates made to spur academic conversation can be less exact.

Recommendation	For	Impact	How it works
1.1 Estimate flight emissions using recorded data	GPP	The GPP can monitor the amount of emissions produced by air travel at a given project center	• Collect travel data through the GPP • Use that data in the flight calculator • Emission estimations for each project center are produced
1.2 Estimate ground travel and living accommodation emissions	Project Directors	Project directors, advisors, and students can be made aware of their carbon footprint	• Accredited methods of estimation are determined • Methods are reported to and approved by the GPP • Estimations for each Project Center are produced
1.3 Compile and sum all emissions data	GPP	The GPP can determine the total emissions produced at a given project center	• Collect air travel, ground travel, and accommodation emissions from each project center • Sum emissions estimates to generate a total figure
1.4 Utilize the carbon emission calculators generated by this IQP	PRPC & Project Directors	PRPC Students and Project Directors can use the calculators to easily generate rough estimates of varying aspects of the IQP Program	• Data is inputted into the calculators • Estimations representing categories of IQP emissions are produced

Figure 11: Overview of estimation recommendations

Emission estimation for the purpose of carbon offsetting (1.1 - 1.3).

1.1 Estimate Flight Emissions Using Recorded Data

Goal:

The Global Projects Program is recommended to use IQP air travel data to generate emission estimations for the round-trip air travel taken to each project center. This method of estimation will generate total air travel emissions estimations for each project center. The data for all project centers can then be summed to create an estimate for all IQP air travel in kilograms CO_2.

The methods used to estimate air travel emissions can be the same for every project center. Also, ensuring the legitimacy and reliability of emissions estimation methods is critical to any further analysis. Therefore, air travel estimation should be centralized at the Global Project Program level. This model will allow for the standardization of the estimation methods used, ensuring consistency across project centers.

Process:

The Global Projects Program is recommended to use an accredited commercial emissions calculation service to estimate IQP air travel emissions (see Company Table in section 3).

1. An estimate of air travel emissions for each Project Center can be generated by the commercial service using IQP flight data collected by the Global Projects Program as input.

2. Project Center estimates can then be totaled to generate an overall IQP Program estimate.

1.2 Estimate the Ground Travel and Living Accommodations Emissions

Goal:

Project Center Directors will determine methods for estimating emissions for living accommodations and project-related ground travel generated by their respective site(s). Variability of regional energy profiles and modes of project-related ground travel makes it difficult to centralize the estimation methods used. Therefore, these estimation methods should be developed at the Project Center level.

Process:

Preferred:

- Project Center Directors should identify accredited carbon emission estimation services that can provide an estimation for the living accommodations and project-related ground travel of their site.
- Emissions estimations are generated using the accredited service and reported to GPP.

Otherwise:

- If applicable to the Center, Project Center Directors should make IQP projects out of emissions estimations.
- While these estimations will likely not have certification, they provide a rough estimate of the problem that can be used to start more concrete conversation on the issue.

1.3 Compile and Sum Up All Emissions Data

Goal:

The Global Projects Program receives estimates for the emissions generated by living accommodations and project related ground travel from project centers. These estimations are combined with air travel emissions to generate overall emissions estimations for each Project Center and the entire IQP Program.

Centralization of Project Center emissions estimation data at the GPP level is logical because it allows for the standardization of emission estimation methods. Also, centralization will best facilitate the analysis and summation of Project Center estimates.

Process:

1. A level of standardization for estimation methods and accreditations should be determined.
2. Project Centers report emissions estimations for living accommodations and project related ground travel for their respective site(s) to the GPP.
3. Estimations for living accommodations and project related ground travel are then added to the Project Center's respective air travel estimation to determine an overall estimation for a given Project Center.
4. Total Project Center emission estimations should be provided to their respective center directors.
5. Once determined, methods of estimation can be used annually to determine carbon emissions generated at each Project Center and ultimately the entire IQP Program.

Emission Estimation for the Purpose of Academic Discussion (1.4)

1.4 Utilize the Carbon Emission Calculators Developed by this IQP

Goal:

Center Directors are recommended to utilize the Cohort Air Travel Carbon Emissions Calculator developed by our team. This tool can be used to calculate a rough estimate of the air travel emissions generated by a cohort travelling to and from their Project Center. The methods the team used to calculate air travel are not region specific and can be applied to any location.

Puerto Rico Project Center IQP students are recommended to use the PRPC IQP Carbon Emissions Calculator developed by our team. The calculator is designed to require minimal student input to calculate a rough estimate of the individuals carbon emissions produced on IQP. The total emissions figure is produced as the sum of air travel, living accommodations, and ground travel emissions estimates.

The goal of these calculators is to spark academic conversation regarding IQP emissions. Providing students of the PRPC and the center directors and advisors of the greater IQP Program with a relatively simple method to calculate a rough estimate of their own IQP emissions begins to accomplish this, prompting discussion on the estimation methods used and the estimates themselves.

Process:

IQP Cohort Air Travel Carbon Emissions Calculator

1. A Center Director will input the primary flight route taken to their respective project center and the number of individuals in their cohort into the spreadsheet.
2. The spreadsheet generates a rough emission estimate by multiplying round-trip emissions by the number of individuals in the cohort.

PRPC IQP Carbon Emissions Calculator

1. Students will input data for their IQP air travel, living accommodations, and ground travel.
2. The calculator will produce a rough estimate of the total carbon emissions generated by the student's IQP trip.

For more information on the calculation methods and data sources see Emissions Calculator Deliverable Documentation.

Roadmap Step 2: Reducing Emissions

Once emissions are estimated, the next step is to reduce emissions by avoiding activities with high emission production and limiting those activities where they cannot fully be avoided. Unfortunately, in the case of the Global Projects Program, travel emissions are often difficult, if not impossible, to avoid. Air travel often lacks useful alternatives as most project centers require a flight to reach. Students on IQP need to travel and stay in some type of living accommodation, which may produce more emissions than their typical housing in Worcester. Therefore, reducing emissions is the next critical step in improving the sustainability of the Global Projects Program. Emissions caused by a hotel stay add up significantly over the course of a term spent on IQP, alongside project and recreational travel and emissions produced by the living habits of the students, the number of emissions that just one student produces are very quickly growing. While the IQP is an academic and project-based experience, it is important not to forget that these students and advisors are tourists in these new locations and that comes with a lot of additional emissions to simply staying at home living day to day life. Without taking away any of the benefits of the project work or the travel and culture, limiting unnecessary emissions is an efficient way to work towards a meaningful and sustainable IQP experience.

Recommendation	For	Impact	How it works
2.1 Open more domestic project centers	GPP	Travel to and from domestic project centers will generate fewer emissions than that of international project centers	• Phase out further away project centers that are losing interest • Put a stronger focus on new project centers closer to Worcester
2.2 Limit unnecessary travel	Project Directors	Limiting personal travel of great distances while at a project center reduces additional emissions	• Limit students' ability to fly out of the area their project center is located in • Limit long distance personal/recreational trips
2.3 Utilize more sustainable travel methods	Students	Limiting higher level travel emissions reduces a student's overall carbon footprint	• Use carpooling, public transportation, and walking when possible to avoid higher personal emissions • Limit frequency of transportation
2.4 Practice more sustainable living styles and habits	Students	Making small changes in living habits will reduce a student's overall carbon footprint	• Turn lights off • Turn the A.C./heat down or off when not in use • Buy locally sourced food and items

Figure 12: Overview of reduction recommendations

2.1 Incentivize Opening More Domestic Project Centers

Goal:

Decreasing air travel is a significant step in moving towards a net-zero carbon Global Projects Program. Phasing out project centers with low interest and creating new project centers closer to WPI will decrease the overall quantity of emissions produced by air travel. There are no reasonable alternatives to air travel other than not traveling, as less emissive alternative air travel methods are not commercially available yet. Only a very small number of project sites can be driven to, and most sites are too far to take anything other than a plane. Because traveling for an IQP project is such an important part of the experience, and many projects involve contributions to carbon reduction efforts, though difficult to quantify, cancelling travel to project centers is not a viable option.

Process:

- Determine Student interest in project centers
- Phase out further project centers with low interest
- Create new domestic or nearby international project centers or increase traffic to closer project centers

2.2 Limit Unnecessary Travel

Goal:

While on IQP, students are present on site typically in 2 capacities: first as a student, but secondly as a tourist. As tourists, students will travel a lot to make the most of their time while in a new place, and as such, this recommendation aims to reduce emissions caused by all forms of travel for tourism. Ridesharing services increase emissions from idling without passengers and incur additional costs due to the congestion increase caused by additional vehicles on the roads. Unnecessary flights would also add to the carbon footprint significantly. Some sites already limit the travel of students, such as the Morocco project center not allowing students to fly out of the country, although this is for safety reasons instead of environmental reasons. Our team is also aware that travel restrictions like this are less needed or unnecessary in sites with widely available public transit systems like London, and that restrictions may impose problems for travelling at sites like Melbourne, where it is necessary to fly several weekends of the term for students to be able to go everywhere they need to.

Process:

- Discuss with students about staying closer to accommodations for tourism
- Encourage students to walk distances less than a certain amount. This amount depends on the project center. This recommendation is made assuming that it is safe to walk, and that weather permits walking.

2.3 Utilize More Sustainable Travel Methods

Goal:

As mentioned under 2.2, students are required to travel significant amounts while on IQP. This recommendation aims to reduce emissions caused by ground travel by informing students on how to make better travel decisions and increase the efficiency of transportation used by students while on IQP. In surveys given to students at the Puerto Rico Project center for methods of ground transportation, Uber accounted for about 55% of responses, with the next most common form of transportation was public busses with about 30% of responses. The remaining 15% is split amongst other methods such as rentable scooters and walking. The most emissive of these by far is Uber. According to Ward et. al., while ridesharing services reduce cold-start emissions by up to 60%, vehicles running without passengers leads to about 20% more fuel consumption and approximately a 60% increase in external costs brought about by congestion, crashes, and noise. For these reasons, our team believes that the use of Uber is not ecologically viable. Once again, as with recommendation 2.2, project centers with widely available public transportation may not need to implement these policies to the same extent as those without.

Process:

- Encourage students to walk or use public transportation more often in places where ridesharing is typically used.
- In the event a ridesharing service is necessary, students should try to form larger groups when using those services.
- If reasonable for a project center's use, contracting travel to project sites can be a more sustainable option. Several groups at the Puerto Rico project center this term had vans to take them about 40 minutes inland to their site, and our team estimated these vans to be more efficient than using Uber.

2.4 Practice More Sustainable Living Styles and Habits

Goal:

Living in an unfamiliar place with different available facilities requires some adaptation from students. Often, this leads to fewer sustainably minded decisions. This recommendation aims to reduce emissions caused from time spent in housing, specifically hotels. The emissions estimated for a stay in a hotel add up significantly over time, and over a full IQP cohort. Outside of CO2 emissions, water use, chemical use, and plastic use are significantly increased from living in a hotel, mainly because of the cleaning services provided and significant number of single-use plastics used by hotels.

Process:

- Make a checklist of the different things you do that could increase your carbon footprint: leaving the lights on when you leave, leaving the AC on, leaving the faucet on when brushing your teeth, taking long showers, etc.
- If living in a hotel, try to use fewer single-use plastics and abstain from having towels and sheets replaced daily.

Roadmap Step 3: Carbon Offsets

For emissions that cannot be reduced or eliminated, utilizing carbon offset programs is the next best way to neutralize the negative environmental impacts caused by the Global Projects Program. Four different types of carbon offsets were researched to find the pros and cons of each type: forestry and conservation, renewable energy, waste to energy, and community projects (EIC, 2020). Additionally, vetting and ensuring the credibility of carbon offset companies is an important aspect of choosing a carbon offset program. Not all carbon offsets are created equal, and certain carbon offset programs may not actually be offsetting the emissions as promised and could even have a negative effect on the environment (Song, 2019). An example of this is that many reforestation projects do not consider biodiversity and an area's ecosystem, but instead plant a single species of trees that have high carbon absorption capabilities (Carbon Offset Guide, 2021). Once planted, these trees often do not survive and ultimately hurt the ecosystem of the area in which they were planted. Additionally, the public perception of carbon offsets should be considered. There are many negative associations with carbon offsets being a lazy, or "band-aid," fix since they offset emissions that have already been produced rather than reducing or eliminating emissions before they happen. Because of these findings, the team outlined ways to navigate carbon offset companies and programs and provided three suggestions for vetted companies that WPI could potentially use.

Recommendation	For	Impact	How it works
3.1 Partner with a carbon offset company to offset GPP travel emissions	WPI & GPP	WPI and the GPP can offset GPP emissions though a structured partnership with a reliable and well-researched offset company	• Look into Worcester carbon offset companies that can help at home • Look into carbon offset companies that work with universities or do large-scale projects.
3.2 Create a group dedicated to monitoring the credibility of offset companies	WPI & GPP	WPI and the GPP can ensure that the companies WPI partners with do not lose their reliability overtime	• Stay up to date on the work that the offset companies are doing • Stay aware of any sign of misrepresentation of the work being done
3.3 Encourage the individual use of vetted green tags/ carbon offsets for the flights of faculty and students	GPP & Projects Directors	Thoroughly vetted green tags can help to reduce the net emissions caused by flights	• Encourage students that travel beyond their center to use vetted green tag/carbon offset programs • Encourage students to do their research and use best judgement

Figure 13: Overview of emissions offsetting recommendations

3.1 Partner with a Carbon Offset Company to Offset GPP Travel Emissions

Goal:

Partnering with a carbon offset company would be highly beneficial to WPI's progress towards carbon neutrality, however, it is important that the correct company is chosen. Carefully researching and vetting offset companies helps to avoid companies that use offsets with low effectiveness or longevity and ensures that WPI doesn't partner with a company that fails to properly deliver on their offset promises. The credibility of offset companies is often supported by third party auditors, such as the Gold Standard and the American Carbon Registry, that are responsible for making sure that the projects the offset companies are doing are effective and honest. A credible offset company will have gone through a certification process for each offset project with an auditor ensuring that the project uses scientifically proven methods and effectively offsets emissions (Native Energy, 2021). Once the vetting process is complete, WPI and the GPP can partner with a carbon offset company to begin offsetting emissions produced by travel abroad.

Process:

- Look for companies advertising carbon offsets that include renewable energy
- Ensure that companies have 3rd party audits and have been verified
- Partner with at least one carbon offset company that could provide offsets on a GPP level
- Offsets would be financed by WPI and the GPP

Below is a breakdown of the three companies that this project deemed best to look further into and potentially partner with. The chart provides a summary of the companies, the different offset projects they use, and the 3rd party auditors that they are accredited by. This shows a brief overview of each company, listed from 1st to 3rd in terms of how highly this program recommends them. While this allows WPI insight into these companies, it is important that further analysis be completed before ultimately selecting one to partner with.

Company	Overview	Offset Type	3rd Party Auditors
native A Public Benefit Corporation	• Help Build™ Carbon Projects • Certified B Corp • Public Benefit Corporation • Work with Middlebury College • Business & Individual Offsets • Global Projects • $15.50 per metric ton CO2	• Carbon Sequestration • Clean Water • Forests & Biodiversity • Regenerative Agriculture • Renewable Energy	• American Carbon Registry • Climate Action Reserve • Climate, Community, and Biodiversity Alliance • Gold Standard • Plan Vivo • Verified Carbon Standard
SUSTAINABLE TRAVEL INTERNATIONAL	• Aligned with United Nations Sustainable Development Goals • Travel Focused • Business & Individual Offsets • Global Projects • $12.36 per metric ton CO2	• Carbon Sequestration • Forests & Biodiversity • Local Communities • Renewable Energy	• American Carbon Registry • Climate Action Reserve • Climate, Community, and Biodiversity Alliance • Gold Standard • Plan Vivo • Verified Carbon Standard
terrapass	• Personal Carbon Offsets • Flight Carbon Offsets • EcoTourist Bundle • Renewable Energy Certifications • Business & Individual Offsets • Global Projects • $15.00 per metric ton CO2	• Agricultural, Landfill, and Mine Methane Capture • Forests & Biodiversity • Ozone Depleting Substance Destruction • Renewable Energy	• American Carbon Registry • Climate Action Reserve • Gold Standard • Verified Carbon Standard

Figure 14: Comparison of potential offsetting companies

3.2 Create a Group Dedicated to Monitoring and Maintaining the Validity of Offset Companies

Goal:

By having a group within the GPP to monitor the validity of carbon offset companies, WPI and the GPP can ensure the companies they work with are effective and honest. If any company loses its credibility, this group will alert WPI and the GPP to discontinue any further work with them. During a discussion with project center directors, the directors expressed concern that it might be hard to execute carbon offset projects at a project center director level, so having the carbon offset companies being vetted at a GPP level would be more manageable and likely successful.

Process:

- Create a task force or committee of members from the GPP, WPI faculty, students, etc. to audit carbon offset companies and decide if WPI should work with them.
- Make a yearly audit of carbon offset companies being used.

3.3 Encourage the use of Vetted Green Tags for Personal Flights During IQP

Goal:

Students and faculty can offset their air travel emissions by independently purchasing green tags or carbon offsets. Encouraging this act would allow students and faculty to make the choice to offset their own emissions and be cognizant of their impacts while flying.

Process:

- A search for independent green tags or offsets can begin with some airlines and hotels that have green tags which specifically offset flight emissions.
- These tags are usually relatively inexpensive, but we recommend that WPI compensate or offer some sort of incentive for purchasing green tags.

Roadmap Step 4: Climate Projects

In addition to the primary focus of this project, determining strategies to estimate, reduce, and offset the emissions of the WPI IQP Program, we recommend the promotion of IQP project work done to combat and adapt to climate change. The climate crisis is a global problem that is contributed to by anthropogenic emissions from all around the world. Any project work done to estimate, analyze, or reduce the carbon emissions of an entity or organization is a step in the right direction. Projects that work in communities or ecosystems to improve resiliency and adaptability to climate change are also important, especially in locations vulnerable to its effects. A large body of the IQP work done at WPI already aligns with this sentiment with projects in community resiliency and the estimation, analysis, or reduction of emissions – a search on digitalwpi.wpi.edu for “carbon estimation” returns 153 results between 2011 and 2021 when filtered for IQPs, and another 62 appear in the same timeframe when searching for “climate resiliency. The following recommendations are intended to bolster this focus within the IQP Program, and to ensure that this line of work continues to grow in the future.

Recommendation	For	Impact	How it works
4.1 Include mitigation, adaptation, and resiliency projects in all project centers where applicable	Project Directors	These projects help the communities being impacted by Climate Change face the effects of those impacts	• Include projects related to mitigation, adaptation, and resiliency when possible
4.2 Where 4.1 does not apply, provide information to students about small ways to support the community	Project Directors	see above	• Encourage students to look into ways to support the community (e.g., going to a local cleanup on the weekend)

Figure 15: Overview of climate projects recommendations

4.1 Include Mitigation, Adaptation, and Resiliency Projects in all Project Centers Where Applicable

Goal:

Many communities in the areas that WPI has project centers have a high risk of being affected by the impacts of climate change. Part of the research done on site for this project involved spending a few days at other project sites and speaking to their sponsors. The biggest take-away from these trips was how important these projects are to sponsors and how much it impacted their communities. An example that shows this well is the example of the groups working in Cubuy to create a community center. The community center is being built from an abandoned school to become a place where members of the community can go to get food, education, medical support, and ultimately shelter when storms make that necessary. One project team was tasked with helping design the space and create methods of outreach, while the other was assigned the task of planning a green roof, which involved deciding where solar panels and water entrapment systems could be placed. Speaking with the sponsor of these projects made it clear how important the work of the two teams was. They spoke of times when water was gone for weeks on end and times when family members couldn't reach medical help in time due to the distance from a hospital in their community. This conversation, as well as conversations with other sponsors sheds light on the importance of community projects and shows how much of an impact IQP teams can have on small, at-risk communities. While it may be difficult to quantify the impacts these projects have, they make a substantial difference, nonetheless. For these reasons, project centers should include at least one project that helps increase the resilience of the community to the effects of climate change.

Process:

- Create IQP projects that relate to climate change and impact community resiliency
- Find local sponsors in the area of the project center that want to continue creating resiliency projects each year (these could even be projects that build off each other

4.2 Provide Information About Ways to Support Communities

Goal:

Some project centers have a specific focus for their projects that do not align with climate and resiliency actions, so these centers would likely not go out of their way to create different projects. However, students and faculty can be encouraged to support the community they are staying in in small ways, whether it be supporting local businesses or attending local events in support of resiliency. Our team hosted an open zoom discussion for project center directors to voice their opinions about this project and its goals and a valid concern was brought to light during this discussion. Some project centers are in areas that simply don't have the resources or sponsors or even need for entire resiliency projects and asking advisors to force a project that doesn't fit, is not helpful to the student IQP experience, nor to the communities. However, this combined with a beach cleanup completed here in Puerto Rico during IQP, inspired the creation of a secondary recommendation. Making students aware of community volunteer activities they can participate in is not only helpful to the community's environment, but to enrich the students' experience by getting more hands-on experience in these new communities.

Process:

- Communicate with sponsors about community events that teams can take part in
- Encourage students to get to know the community and ask questions about how climate change has affected the community they are working in

Roadmap Step 5: Climate Literacy

To effectively move towards climate neutrality, it is important that the entire campus of WPI have a solid understanding of climate change and its various impacts on it. There are limited actions that can be taken to efficiently stop emissions if there is not first an understanding of what those emissions are. While the numbers of emissions can be calculated and this outlined plan can be followed, in order to make conscious collective and individual changes, there must be a deeper climate literacy promoted. This is not to say climate literacy does not exist on campus, as many students and faculty take time to support it,

however, the hope is to expand and enrich the climate literacy of the campus overall. Speaking to a variety of stakeholders throughout the entire length of the project it was found that many students have a lot they wish to learn about emissions and climate change, and many believe that WPI should be implementing this as a larger piece of WPI's curriculum.

Recommendation	For	Impact	How it works
5.1 Provide education in ID2050 regarding the climate crisis and an individual's impact	Project Directors	Students will be more conscious of their carbon footprint and environmental impact while abroad.	• Integrate a lesson into the module of ethics in ID2050 • Use activities, games, short lectures, videos, etc. to encourage climate literacy
5.2 Encourage climate literacy throughout normal coursework	WPI	Students and faculty will be more environmentally conscious	• Incentivize professors to integrate climate literacy into their coursework • Create climate focused classes required for majors/fields that heavily impact the climate
5.3 Promote information about emissions produced through the GPP	Project Directors	Change will be more likely to occur if students and faculty are made aware of the GPP carbon footprint	• Discuss specific ways that students and faculty produce emissions • Offer time to discuss potential ways to limit emissions during ID2050
5.4 Create Eco-Rep teams durirng the IQP experience	Project Directors	Eco-Reps will not only create a greater ease for spreading information and gathering data, but also will spark strong limate focused discussion	• Select one member from each project team to be their Eco-Rep • Use a developed form of communication to share infrmation • Encourage Eco-Reps to share information in discussions with their teams
5.5 Sign the pledge for Race to Zero	WPI	Signing the pledge will push WPI toward carbon neutrality and sustainability awareness	• Sign the pledge to agree to work towards net zero emissions • Report progress updates on actions and goals yearly

Figure 16: Overview of climate literacy recommendations

5.1 Provide Education in ID2050 Regarding the Climate Crisis and an Individual's Impact

Goal:

After not only speaking to students, but also to a focus group of project center directors, it was discovered that there are a variety of opinions when it comes to climate literacy on campus. While most agree that it is important to include, the argument was on whether it was truly a core piece of ID2050. Some center directors stated that climate literacy was already being addressed, while others weren't seeing it as a focus in the course. For that reason, it is recommended that WPI has a more uniform agreement that ID2050 should include climate literacy. ID2050 is a course designed to prepare students for their IQP experience. This includes preparation for the project itself, but also for what to expect in the area that the students are travelling to. Within this course there is often a section on ethics where students learn about

how to have strong ethical considerations towards the stakeholders of their projects. This would be an excellent time in the course to address the fact that the environment and the climate are indeed stakeholders in all IQP projects. The work done during projects and simply the travel and living accommodations used to support these projects can have very real impacts on climate change. Addressing these issues thus appears to fit best in the context of ethics so that students can understand the full extent of their impacts. Another concern brought to our attention is how plausible it is to take a large chunk of time away from ID2050, while still understanding that too small of a climate literacy discussion will not promote any change. Therefore, we strongly suggest that it be included in the ethics section, as that is already a very important and strongly focused section that students tend to gain a lot from.

Process:

- Using a variety of resources, advisors and or center directors who are teaching ID2050 will incorporate a climate literacy section into their curriculum.
- While we recommend that this fits into the ethics section, it is up to those teaching the courses to decide where they feel it fits best for their class and their location.
- Location based challenges and statistics should be used to ensure that the knowledge gained in this course is specific to the location in which the students' projects will take place
- While it is true that some professors already take the time to address climate change, the plan is to standardize this into a core piece of the ID2050 curriculum.

5.2 Encourage Climate Literacy Throughout the Normal Coursework

Goal:

While the ideal location for climate literacy is ID2050, especially with this project focusing on the impacts of the IQP, it is not the only place it should be encouraged. To be climate literate is an ongoing process and it is difficult to claim to be climate literate after one module in a singular seven-week class. However, if modules or exercises addressing climate literacy were present in all classes where it fits, students would be more well-rounded and more climate literate overall. When speaking to a member of the WPI student body about their thoughts on climate literacy, a substantial piece of their argument to increase it was that much of the work WPI students will end up doing in life has impacts on climate change. As a school of mostly engineers, the students are typically going into fields of work that have very large impacts on the environment and the climate. With that, there are a lot of ethical concerns that

appear in that work and giving students the chance to enhance their climate literacy while in school ensures that they are better prepared for these real-life experiences in the work force.

Process:

- Using a variety of resources, professors will incorporate a climate literacy section into their curriculum.
- This can appear as an entire module or a singular activity to stimulate thought. This depends on the class and how well suited the topics are to climate literacy
- This section, while important, should be less grade focused and more focused on the idea of inspiring discussion and growing climate literacy

5.3 Promote More Information About Emissions Produced on IQP

Goal:

A large issue with reducing carbon emissions is that many people don't fully understand what their emissions are, or how they can limit them. Advisors and Directors specifically should be more open with students about the truth of how much they are producing when they go away on IQP. If students are provided with actual numbers of emissions and tools to limit them, they will be more likely to understand what is happening, and thus more likely to work to reduce their personal emissions. A survey of the students on IQP here in Puerto Rico showed that many of them were not clear on how they were creating emissions and how large those emissions were. Many even asked if limiting certain emissions would be beneficial and in what ways they would be. This shows that college students going on IQP are not entirely clear on what that means for their impact on the environment, or how they can create change, however small that may be. Every small change can be equally important, because if hundreds of WPI students are making small changes every year, those changes add up to be something so much bigger.

Process:

- Create a platform in which emissions calculated for the IQP experience can be visible to students on IQP
- Using emission reducing resources and tools, provide students with examples of plans they can set for themselves when on IQP to limit their personal emissions
- Take time in ID2050 to brainstorm ways that emission may be produced and ways to limit them. This will get students to really start thinking about their impacts.

5.4 Create Teams of Eco-Rep's During the IQP Experience

Goal:

Climate literacy is recommended to be a key piece of the IQP experience, not only in the preparation, but in the practice as well. While on IQP students will have many focuses and will often forget or lose sight of issues discussed in ID2050 in the craze of completing their projects and enjoying themselves in a new area. The goal is that in addition to the project work and enjoyment, the idea of climate literacy is not lost. This is where Eco-Reps would come into play. The Eco-Reps that volunteered to aid in the data collection of this project were not only helpful to the project's success, but also to keeping conversation alive about the climate crisis in each group. An Eco-Rep is one volunteer from a project team that is the main point of contact for the team for all things regarding climate. For the purposes of this project, the idea was created simply with the intention of gathering more reliable data for students' emissions. However, as survey responses were reviewed it became clear that these students were actively discussing topics with their respective teams and providing us with questions and opinions that they had regarding these issues. By continuing this into an Eco-Rep program that functions throughout IQP centers, these discussions will continue, encouraging students to really examine and understand their personal emissions and climate impacts, and what they can do to work towards carbon neutrality and a more sustainable IQP.

Process:

- During ID2050, advisors will ask each team to submit the name and contact information of one team member who will act as their Eco-Rep

- An email alias or other form of generalized communication should be built for advisors to easily address all the Eco-Reps
- Beginning either in ID2050, or the start of IQP, the advisors are encouraged to use this method of communication to gather team data, ask for learning topics students wish to see, send relevant information for tips on sustainable living or local community activities, and any other climate related concerns or points of view
- Eco-Reps are then encouraged to take that information to their team thus spreading awareness and overall climate literacy

5.5 Sign the Pledge for Race to Zero

Goal:

When addressing the emission of IQP, it is hard to view them as WPI's emissions because they are being produced somewhere else. However, these trips are causing WPI's carbon footprint to increase substantially as a university by increasing their net carbon emissions. By signing the pledge to Race to Zero, WPI is agreeing to work towards carbon net zero by the end of the decade. What this means is not that WPI will have zero emissions, but that they will reduce what emissions they can, and offset those they can't, thus creating a net zero. Signing this pledge will put more pressure onto WPI and the GPP to accomplish all the goals set within this plan, as they all work towards a carbon neutral IQP experience. By giving the incentive of a "due date" for net neutrality, more action is likely to take place sooner. Speaking with other groups who have tried to enact change in WPI, it is clear there are a lot of steps to go through and various people to talk to, these kinds of changes take time. By signing this pledge, it is not expected that this change will suddenly take less time but hopefully it will cause more time to be set aside for this purpose.

Process:

- Pledge: Pledge to reach net zero carbon emissions by 2030 and to stay in line with the goal of limiting global warming to 1.5 degrees Celsius.
- Plan: Within the first year of signing the pledge, create a plan to address short, medium, and long-term goals
- Proceed: Take immediate action towards reaching the goals you set
- Publish: Publish publicly your progress and plans moving forward, at least yearly
- More detailed information on these steps can be found in the race to zero resources in the Resources/Tools section below

Roadmap Resources

Resources for Estimating Emissions

- Air Travel Estimation
    - **ICAO Website:** https://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx
    - **ICAO Methodology:** https://www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v11-2018.pdf

- Living Accommodations Estimation
    - **HCMI Website:** https://sustainablehospitalityalliance.org/resource/hotel-carbon-measurement-initiative/
    - **Hotel Emissions Case Study:** https://upcommons.upc.edu/bitstream/handle/2117/111140/coastland-hotels_authors%20final%20version.pdf
- Ground Travel Estimation
    - **Average Fuel Consumption Data by Vehicle Type:** https://afdc.energy.gov/data/10310

Resources for Reducing Emissions

- **A list of several green hotel programs, both domestic and international:** https://www.epa.gov/p2/green-hotels-resources-ecolabels-and-standards
- **Hotel emissions case study:** https://upcommons.upc.edu/bitstream/handle/2117/111140/coastland-hotels_authors%20final%20version.pdf
- **Some tips for sustainable living:** http://www.globalstewards.org/ecotips.htm (Some may be a little extreme for students on IQP, but all should be effective.)

Resources for Carbon Offsets

- **Native Energy:** https://native.eco/
- **TerrePass:** https://terrapass.com/
- **Sustainable Travel International:** https://sustainabletravel.org/
- **Gold Standard Certification:** https://www.goldstandard.org/
- **Climate Action Reserve:** https://www.climateactionreserve.org/how/offsets-marketplace/
- **Verified Carbon Standard:** https://verra.org/
- **American Carbon Registry:** https://americancarbonregistry.org/
- **Plan Vivo:** https://www.planvivo.org/
- **Climate, Community, & Biodiversity Alliance:** https://www.climate-standards.org/

Resources for Climate Projects

- **The Climate Stories:** https://global-lab.wpi.edu/storying-climate-change/
- Relevant IQP Projects
    - **Climate Change Resiliency:** https://digitalwpi.wpi.edu/catalog?f%5Bmember_of_collection_ids_ssim%5D%5B%5D=iqp&locale=en&q=Climate+Resiliency&search_field=all_fields

- **Energy Efficiency:** https://digitalwpi.wpi.edu/catalog?utf8=%E2%9C%93&locale=en&search_field=all_fields&q=Energy+efficiency

Resources for Climate Literacy

- Examples of Educational Modules and Exercises
  - **Following this entire program enhances climate literacy**
  - **Climate literacy: The Essential Principles of Climate Science:** https://downloads.globalchange.gov/Literacy/climate_literacy_highres_english.pdf
  - **Climate Change and Health Lesson Plan:** https://www.niehs.nih.gov/health/assets/docs_a_e/climate_change_and_human_health_lesson_plan_a_508.pdf
  - **Energy Literacy:** https://www.energy.gov/sites/default/files/2014/09/f18/Energy_Literacy_High_Res_3.0.pdf
  - **CLEAN: Committed to Climate and Energy Education:** https://cleanet.org/clean/literacy/index.html
  - **Global Change reports library:** https://www.globalchange.gov/browse/reports
  - **Activity for mapping emissions:** https://archive.epa.gov/climatechange/kids/documents/mapping-emissions.pdf
- Race to Zero Resources:
  - **Criteria to sign race to Zero:** https://racetozero.unfccc.int/wp-content/uploads/2021/04/Race-to-Zero-Criteria-2.0.pdf
  - **Review process guide:** https://racetozero.unfccc.int/wp-content/uploads/2021/04/Race-to-Zero-EPRG-Criteria-Interpretation-Guide.pdf
  - **Summary of updates to the criteria:** https://racetozero.unfccc.int/wp-content/uploads/2021/04/Summary-of-updates-to-Race-to-Zero-criteria.pdf
  - **Race to Zero for universities:** https://www.educationracetozero.org/home
  - **Sign up:** https://www.educationracetozero.org/sign-up

Chapter 5: Outcomes

Over the course of the project, several documents and deliverables were developed for the Puerto Rico Project Center, Global Projects Program, and the WPI student body.

5.1 Sustainability Proposal Roadmap

The primary focus of this project was to develop a set of policy options and recommendations for the Puerto Rico Project Center. However, as discussions with the sponsors went on, this evolved instead into creating a roadmap of policy options aimed at the entire Global Projects Program. The Roadmap, detailed in Chapter 4, proposes five main steps in moving toward climate sustainability: estimating emissions, reducing emissions, offsetting emissions, climate projects, and climate literacy.

5.2 PRPC Carbon Emissions Case Study

The PRPC Carbon Emissions Case Study was conducted by the team to make a gross estimate of the carbon emissions produced over the course of the term by the cohorts (Cape Town and Albania) conducting IQP at the PRPC. The logic of the case study is to break down the overall estimation into the sum of IQP's major carbon emission components: air travel, living accommodations, and project related ground travel. Below is a breakdown of the methods used to estimate each emission component and a summary of the data collected.

Air Travel

The estimation of air travel emissions is based on the flights taken by the Cape Town and Albania cohorts. The team used a survey to collect data on each student's journey to San Juan and mapped each flight taken as two airport codes: departure and destination (Appendix 2). Survey data was input into the ICAO Carbon Emissions Calculator (Appendix 4) to create individual estimates for each flight. For simplification of calculation, it was assumed that all students were flying economy. To create an individual emissions estimate, the flight emissions of each recorded leg were totaled and divided by the number of students who responded to the survey. The average individual emissions value, multiplied by the total number of students and advisors in both cohorts and then multiplied by two to account for return flights, generated a total estimate of round-trip flight emissions generated by the Puerto Rico Project Center.

Living Accommodations

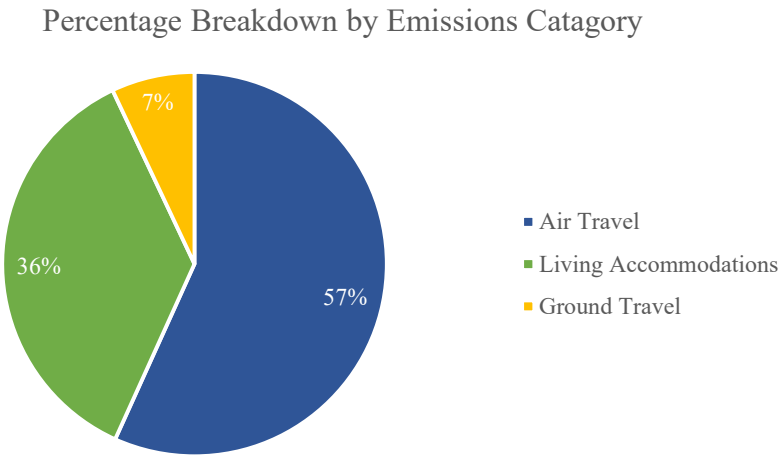
The living accommodation emissions estimation is based on a per room per night emission estimation of the Hotel Marriott in Miramar (PRPC living accommodations). This estimation was made with the Hotel Carbon Measurement Initiative Tool (Appendix 4) and used hotel energy and floorplan data gathered by interviewing the hotel's head engineer (Appendix 2). The total living accommodation emission estimation for both cohorts was made by multiplying the per room per night metric by the number of nights students stayed at the PRPC and by the number of rooms occupied by WPI.

Project Related Ground Travel

The emissions generated by project related ground travel at the PRPC were estimated based on average fuel economy data and survey data collected for each group's project commutes. Survey data was collected over a one-week period to determine the distance travelled to their project site and the mode of transportation used (Appendix 2). Ground travel emissions per commute were estimated based on the distance of the commute and the average fuel efficiency of their mode of transportation. A weekly

estimate was made assuming each group travels to their site an average of 2.5 times a week. The overall total was generated by extrapolating the one week estimate over the whole term. Fuel efficiency data was sourced from the US Department of Energy's Average Fuel Economy by Major Vehicle (Appendix 4).

Case Study Results



	Air Travel	Living Accommodations	Ground Travel	Total
Individual Emissions [kgCO2]	501	320	62	883
Cohort Emissions [kgCO2]	22553	14384	2790	39727
Cohort Emissions [TonsCO2]	23	14	3	**40**
Cohort Emission [% of Total]	57%	36%	7%	

Figure 17: Case study emissions breakdown

The above tables display the results of the PRPC Carbon Emissions Case Study. The overall estimate for the carbon emissions produced by students in the Cape Town and Albania cohorts at the PRPC was 40 metric tons of CO_2. Air travel emissions accounted for the largest percentage of the estimate followed by living accommodations and ground travel. Individual estimates for living accommodations and ground travel were calculated by dividing the respective cohort figure by the number of students in both cohorts. Average individual emissions were then summed to produce the individual total.

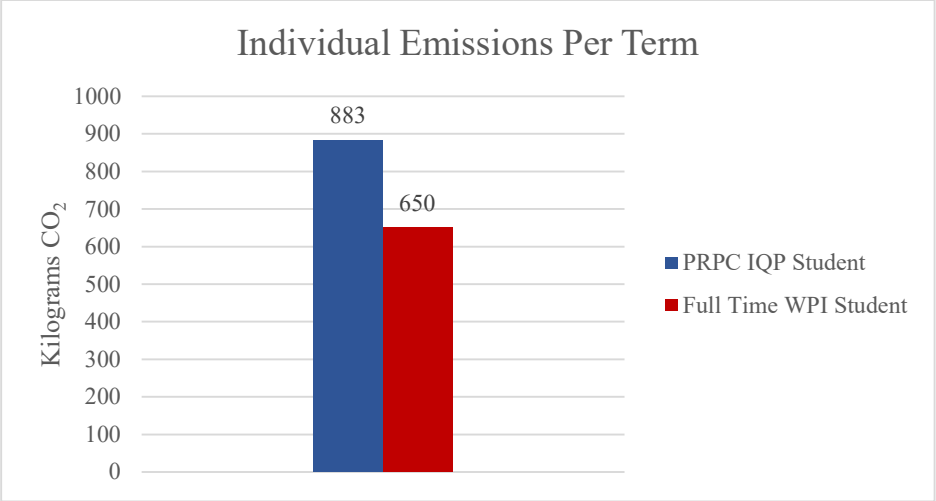


Figure 18: Emissions comparison between a Worcester and a PRPC student

As a point of reference, in 2020 the greenhouse gas emissions generated by a full-time student at WPI was roughly 2.6 metric tons of CO2 or 650 kilograms of CO2 per term (Sustainability Report, 2020). The individual estimate of 883 kilograms of CO2 for the PRPC IQP is roughly 35% greater than this figure.

5.3 Carbon Emissions Calculator Deliverables

The team developed two calculator tools that can be used to estimate the emissions generated by various aspects of the IQP program. It is important to note that these calculators are a simplification of more complex estimation methods researched and lack any form of certification. For these reasons, it is not recommended that the calculators developed by our team be used for carbon offsetting purposes in their current form. These tools are intended to provide rough estimates showing where emissions can be reduced and to spark conversation on the issue of IQP emissions. For more information on the methodologies and data sources used see Appendix 5: Calculator Documentation.

PRPC IQP Carbon Emissions Calculator

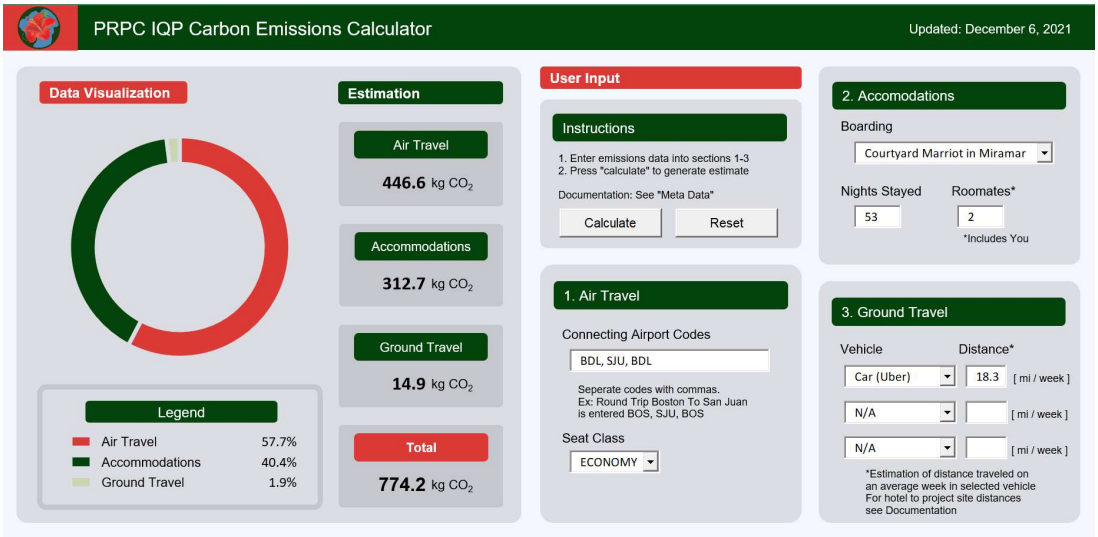


Figure 19: Sample view of the emissions calculator

The PRPC IQP Carbon Emissions Calculator is a tool developed for the Puerto Rico Project Center that uses student input to calculate an individualized estimate of the carbon emissions produced by their trip. The calculator was developed in Excel to automate the methods of the PRPC Emissions Case Study (5.2) and produces a total figure as the sum of air travel, living accommodations, and ground travel emissions estimates. The calculator is designed to require minimal user input to produce a student's estimate.

IQP Cohort Air Travel Emissions Calculator

The IQP Cohort Air Travel Emissions Calculator is a tool developed for all IQP Center Directors and Advisors that can be used to calculate a rough estimate of the air travel emissions generated by a cohort travelling to and from their Project Center. The spreadsheet uses the individual emissions estimate of a primary flight route to a Project Center as a metric. This metric is then multiplied by two to account for a round trip journey and by the number of individuals in the cohort to produce a total estimation. The methods the team used to calculate air travel are not region specific and can be applied to any project center.

5.4 Website

As a cumulative representation of the project, a website was created to not only share background information, but also to provide access to all deliverable outcomes in one easily accessible location. The flow of the website similarly follows the flow of all the deliverable outcomes. It first gives a brief introduction to the project and then through links in the navigation bar, allows the visitor to find further

information about emission estimations, emission reductions, carbon offsets, climate projects, and climate literacy. Within each of these sections there is an introduction to the topic with some brief background followed by a chart of the proposed recommendations regarding that topic. Deliverables hosted on this website include a downloadable version of the team's calculator, this IQP final report, and the proposed policy document. The website can be visited at https://wp.wpi.edu/gppsustainabilityproposal/

5.5 Eco-Reps Program

One of the key points in methodology and one of the recommended policies is the use of Eco-Reps. While during this term they were referred to as "Climate-Reps" the premise is still the same. Eco-Reps are a member from each IQP team that are the main point of contact regarding all thing's climate crisis related. This means that these individuals are tasked with keeping track of the team's project related emission usage while also being the ones to support the conversation and development of climate literacy in their project work. For this project specifically these Eco-Reps were especially helpful in gathering team data to estimate the PRPC's ground travel estimations. While these were only estimations, they not only provided a better idea of what these emissions look like in a quantifiable sense but also allowed students the chance to stop and think about what actions they were taking in a single week that could produce high amounts of CO2 into the atmosphere. Therefore, the continuation of the Eco-Rep program would provide support in estimating emissions, reducing emissions, and climate literacy.

Chapter 6: Conclusion & Recommendations

This project is focused on creating a more sustainable Global Projects Program for WPI. Over the course of the project, we spoke with professors and students at WPI, including several IQP project center directors; students on IQP in Puerto Rico; and to the chief engineer at the Courtyard Marriott in Miramar, where students were being housed for this IQP. Our initial task was to create a climate program for the Puerto Rico project center alone, however over the course of the project we worked to generalize the program to the entire Global Projects Program.

6.1 Recommendations

To create a climate program for the Global Projects Program, it was necessary to understand what the sources of emissions were and how much each source was emitting. To aid with this, research was conducted on several carbon emissions calculators and that research generated the creation of this projects calculators that can be used by any project center to gain a rough estimation of the emissions caused for a group of students to go to that project center. This calculator was used to determine that the PRPC air travel emissions were about 501kg of CO2 per person on average, ground travel caused about 3073kg of

CO_2 for the 46 students present for the term, and emissions caused by the hotel stay to be about 11.8kg of CO_2 per night per room of 2 people, or about 7818kg for an average cohort's stay and 14384kg for the combined cohorts staying 53 days for this project term.

Recommendations regarding emissions estimation: Project center directors and the Global Projects Program should estimate and sum the emissions caused by each individual project center, so that informed decisions regarding carbon reduction and carbon offsetting can be made.

The next step in the program is to directly reduce carbon emissions. This is done by decreasing the actions that lead to emissions. While avoiding and reducing emissions are the most effective ways to reduce a carbon footprint, the number of emissions that can be directly reduced by the Global Projects Program is limited, as air travel emissions cannot be reduced without avoiding flying, which is not a reasonable option for the GPP. Additionally, some project centers, such as the one in Puerto Rico, do not have access to extensive public transportation networks that some cities have, meaning that ridesharing is often a necessity.

Recommendations regarding reducing emissions: The Global Projects Program should create new project centers closer to Worcester, and phase out unpopular distant project centers to reduce air travel emissions. Additionally, it is recommended that project center directors attempt to limit unnecessary travel for students to a reasonable extent, to reduce ground travel emissions. Finally, it is recommended that students develop environmentally friendly habits while staying at their lodgings, such as reducing the number of single-use plastics they use.

After reducing emissions as much as possible, the next step is to offset the remaining emissions. Research was conducted on several types of carbon offsets and used to evaluate their effectiveness against one another. This research showed that while reforestation credits are often sold as offsets, reforestation projects are often not implemented, or when implemented are not followed up on and so frequently trees will be planted and die soon after.

Recommendations regarding offsetting emissions: The Global Projects Program should evaluate the offset companies identified in this proposal and purchase carbon offsets to offset unavoidable emissions caused by travel for IQPs.

While this project aims to reduce emissions caused by the Global Projects Program, it will not do so overnight. Many communities are at an ever-increasing risk of falling victim to the impacts of climate change or have begun to feel the effects already. Because of what the IQP program stands for, the more projects helping improve the climate resiliency of a community near the project center that are offered the better.

Recommendations regarding climate resiliency projects: WPI and the Global Projects Program should offer at least one project focused on improving the climate resiliency of an at-risk community local to the project center. While this is already a frequent practice at some project centers, expanding this to other project centers would be very beneficial.

When speaking with members of the DivestWPI group, a sentiment among them was the belief that WPI students, for the most part, are not typically climate literate. A lack of required classes that focus on climate or similar topics seems to reflect this notion. To improve the carbon footprint of project centers, students first need to be able to understand their individual impacts on the environment, both through their normal actions and through their work, and the critical role that collective action will play in addressing the climate crisis.

Recommendations regarding improving climate literacy: It is recommended that project center directors include more content in ID2050 to help boost the climate literacy of students, and center directors are encouraged to provide more information to students on the emissions they produce while on IQP. It is also recommended that WPI encourage climate literacy and understanding throughout a student's normal coursework. Finally, it is strongly recommended that WPI sign the pledge to the Race to Zero and join the large group of universities pledged towards reaching net zero carbon emissions by 2050 or as soon as possible. WPI has already made strides towards similar goals and joining this group would show full dedication to the messages of sustainability WPI promotes.

6.2 Limitations

WPI's Global Projects Program spans more than 50 project centers over 6 continents, so each project center is unique in what it contributes to the IQP experience, and this is reflected in the lifestyles of students staying at any given center. Unfortunately, that means that any program created for the GPP to improve its sustainability is going to run into cases where recommendations and policies are unneeded, inappropriate, or in effect, even if not for the express purpose of increasing sustainability. Many of the emissions from the Project Center are unable to be directly reduced, meaning that any net-zero plan must rely on carbon offsets and carbon credits to reach its goal. Additionally, the calculations done for emissions estimation for this project, specifically in regard to the hotel stay, are a gross calculation, rather than a net one. This means that we do not take into account the emissions the students are no longer making at their original housing in Worcester.

Appendix 1: Sponsor Note

Over the course of the project, the team worked very closely with project sponsors, the Puerto Rico Project Center and the Office of Sustainability, in order to determine the most effective and feasible actions to take. The sponsors share in our passion for the mission to create a climate program that will promote a more sustainable and restorative Puerto Rico Project Center. The Puerto Rico Project Center focuses especially on issues and topics regarding the climate crisis, so it is important for the center to consider its own impacts on the environment. There have been projects and policies in the past at WPI that focused on this idea, however, nothing concrete has been put in place in terms of a climate program at the Puerto Rico center.

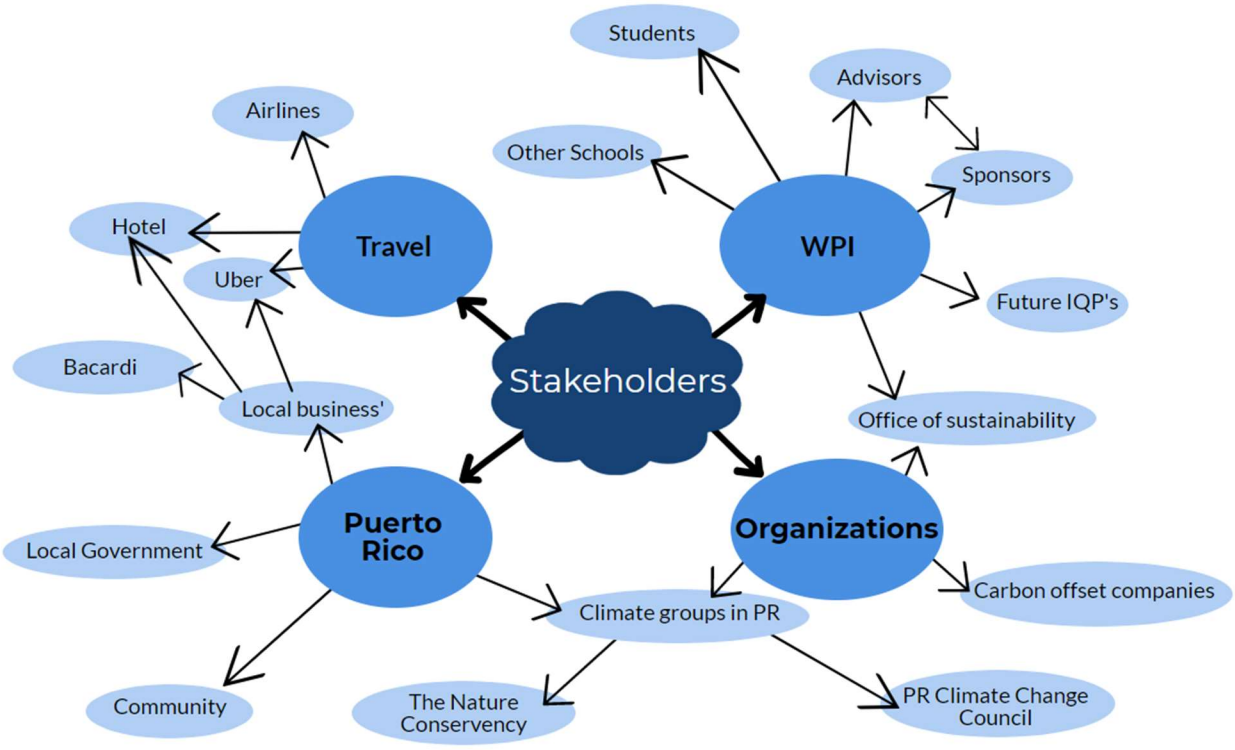


Figure 20: Stakeholder analysis graphic organizing various stakeholders of the project into relevant groups

Appendix 2: PRPC Emissions Case Study Surveys

Air Travel Survey

The flight information of the project center members will be collected in order to estimate air travel emissions.

Survey Questions

1. What airline did you fly with?
2. What airport did you fly from?
3. Did you have a layover? If so, where was it?

Travel Log

The following surveys were sent to the climate representatives of each group to gather information on ground travel at the PRPC. The first version of the survey included both recreational and project travel before it was revised to only project related travel for the second. The second survey allowed the team to generate an estimate for per week ground travel emissions.

Travel Log Survey Questions

1. What project group are you in?
2. When was this trip taken?
3. Is this trip project related or recreational?
4. What is the mode of transportation for this trip?
5. Where did you start this trip?
6. What was this trip's destination?
7. How many people did you travel with (including yourself)?
8. Was this a round trip? (Did you take an uber there and back?)
9. If your travel is project related, what was the total cost of the entire trip in dollars? (75 cents = 0.75) (Data point for WPI's cost evaluation)

Revised Travel Log Survey Questions

1. What project group are you in?
2. What day is this submission for?
3. Did you travel to your project site today?
4. What was the mode of transportation TO the project site for this day?

    a. Uber
    b. Contracted Project Vehicle
    c. Bus (Public Transit)
    d. Other (Specify)
5. How many people (WPI only, ignore other passengers and drivers) were you traveling with (including yourself) TO the project site?
6. If you travelled with another project group(s) TO the project site, which group did you travel with?
7. Did you leave from the hotel? If not, specify where.
8. What was the address/ exact location where you were dropped off at your project site?
9. Was this a round trip? (Did you leave to return to the hotel from this point?)
10. If NO to the previous question, what was the address/ exact location you left to return to the hotel for the day?
11. What was the mode of transportation LEAVING the project site for this day?
    a. Uber
    b. Contracted Project Vehicle
    c. Bus (Public Transit)
    d. Other (Specify)
12. How many people (WPI only, ignore other passengers and drivers) were you traveling with (including yourself) LEAVING the project site?
13. If you travelled with another project group(s) LEAVING the project site, which group did you travel with?
14. If you had to pay for your trip (like if it was an Uber), how much did you pay in total for the day (there and back)? (75 cents = 0.75) (data point for WPI's cost evaluation)

Appendix 3: Interviews and Surveys

Multiple interviews and discussions will be conducted over the course of the project as a way to gather necessary information as well as a variety of perspectives to fulfill the objectives and project goal. Figure 10 is a flow chart that outlines the stakeholders of the project and splits them into four main categories: WPI, Organizations, Puerto Rico, and Travel. The team will aim to interview as many stakeholders as possible within these categories, with the questions for each stakeholder outlined below.

Project Center Climate Representatives

To hear the voices and opinions of the students on IQP in Puerto Rico, the team created a focus group of Climate Representatives to collect the views of the whole project center. Each project group had

one member volunteer to be their Climate Representative, the main point of contact from their team to this project. Group surveys were sent to the Climate Representatives with the goal of prompting climate minded discussion amongst their teammates. In these surveys, there was an entry field where each member of a team would contribute their input and opinion on the topic. The climate representative model helped to make the topic into more of a discussion and made it easier to hold teams accountable for responses. Through this model, the project gained a perspective representative of the larger student body in Puerto Rico on IQP. The goal of these surveys was to learn about students views on the issues of climate change, carbon offsets, and potential policies and changes to the IQP experience.

Climate Representative Intro Survey

1. What Project group are you in?
2. What is your group doing in your project that you think most positively impacts the climate?
3. What made you decide to be the Climate Rep for your team?
4. Have you ever heard of carbon offsets?
    a. Yes
    b. No
    c. Some of us have not
5. What area of the IQP experience do you think needs the most attention and change regarding sustainability? (Select the answer that CLIMATE REP believes is best)
    a. Air Travel
    b. Living Accommodations
    c. Ground Travel
6. What area of the IQP experience do you think needs the most attention and change regarding sustainability? (select answer TEAMMATE 1 believes is best)
    a. Air Travel
    b. Living Accommodations
    c. Ground Travel
7. What area of the IQP experience do you think needs the most attention and change regarding sustainability? (select answer TEAMMATE 2 believes is best)
    a. Air Travel
    b. Living Accommodations
    c. Ground Travel
8. What area of the IQP experience do you think needs the most attention and change regarding sustainability? (select answer TEAMMATE 3 believes is best)

    a. Air Travel
    b. Living Accommodations
    c. Ground Travel
9. What area of the IQP experience do you think needs the most attention and change regarding sustainability? (select answer TEAMMATE 4 believes is best)
    a. Air Travel
    b. Living Accommodations
    c. Ground Travel
10. Do you feel as though you are producing more emissions while on IQP than when in Worcester?
    a. Yes
    b. No
11. Have there been times that you took an Uber and then thought to yourself you could have walked instead?
    a. Yes
    b. No
12. What is one thing you want to learn more about with regards to climate change and the issues that surround it? (include your thoughts and the thoughts of your group mates so we can be sure to cover everyone's ideas)

Courtyard by Marriott San Juan Miramar

The Courtyard by Marriott San Juan Miramar is the hotel that the Puerto Rico Project Center cohort will be staying at for the duration of the IQP. A portion of the project center emissions will come from accommodations, and while estimates can be made using primary sources found in research and independent data collection, reaching out directly to the hotel will allow the team to better estimate the project center's emissions caused by accommodations. The hotel staff will have a more expert understanding of energy usage and sustainability practices, which will be invaluable in estimating carbon emissions.

Interview Questions

1. Are you familiar with carbon offsets?
2. Has the hotel investigated utilizing carbon offsets in the past?
3. Has the hotel taken any other sustainability initiatives relating to carbon emissions?
4. Are you familiar with the green tags program at the San Juan Marriott Resort & Stellaris Casino?
5. How does the hotel collect data on energy use and emissions?

6. Do you use an emissions calculator to determine this information?
7. If not, how do you calculate/record the data?
8. Is this data readily available?
9. Are you a member of any climate organizations or initiatives within Puerto Rico?
10. Are there any climate organizations or initiatives directed towards accommodations/hotel stays in Puerto Rico?
11. Does the hotel track their carbon footprint using a calculator like HCMI?
12. Is the data required publicly available so we could make the estimation ourselves?

(See Appendix 5 for Data)

Project Center Directors

The team surveyed and held a focus group with several WPI Center Directors. The goal was to gain input and insight from other WPI project centers on the topics of sustainability in the IQP program and policy recommendations aimed at the GPP and project center levels.

Survey Questions

1. Name (first and last)
2. What project center(s) do you direct or co-direct?
3. What area of carbon emissions produced on IQP do you think would be most feasible to reduce?
    a. Air Travel
    b. Ground Travel (Ubers, Buses, etc)
    c. Living Accommodations
    d. Food Consumption/Waste
    e. Other
4. Disregarding air travel, do you think the emissions generated by students living at your respective project center are significantly greater than what they would be producing in Worcester? Why or why not?
5. What ideas do you as a project center director have to improve sustainability within the IQP program?
6. Have you ever heard of Carbon Offsets?
    a. Yes
    b. No
7. If yes, please briefly explain your opinion on carbon offsets
8. Any additional comments or questions?

Focus Group Questions

Section 1: Emission Estimation

Policy: The Global Project Program should use recorded flight data to estimate air travel emissions.

1. Would you be willing to have flight emission estimations run on your project site?
2. How feasible do you think this would be to implement?

Policy: Project Centers should estimate emissions for living accommodations and project travel.

1. Where do you think should these estimations be made? GPP level? Advisor level? Student Project level?
2. Where should this information be located so it is most accessible to students and advisors?

Section 2: Climate Literacy

Policy: Teach topics of climate literacy in ID2050

1. What would you do to teach climate literacy in your classes?
2. How much time do you think would need to be spent on climate literacy and how much time out of ID2050 do you think you could reasonably take?

Policy: Encourage including climate literacy throughout normal classwork

1. Do you think climate literacy should be a bigger focus in the curriculum? Where should it appear?

Section 3: Emission Reduction

1. Should IQP students fly to locations if they don't need to be there in person? Should we be using the virtual workspace more in our global projects?
2. What other ways might we reduce our emissions on a individual and project center level?
3. How can we hold students and faculty accountable when it comes to reducing emissions and environmental impacts?

Section 4: Carbon Offsets

1. What are your opinions on carbon offsets and their effectiveness in helping the climate crisis?
2. Are you familiar with any companies in or around the Worcester area that WPI could partner with?
3. What type of carbon offset do you think is most viable? Why?

Section 5: Resiliency Projects

1. How should WPI divide focus between reducing the institutions carbon footprint and improving community resiliency at project sites?

2. We believe this division should be dictated by the communities we are travelling to.
3. Climate change resiliency is a topic of concern in Puerto Rico. How is your location affected by climate change?

Professor Strauss

The team interviewed WPI Professor Sarah Strauss at the recommendation for Professor Leslie Dodson. Professor Strauss is active in the sustainability and climate community on campus, and the team wanted to gain her insight and expertise.

Interview Questions

1. Talking to Professor Dodson, we heard that you will be heading a new community climate adaptation grad program. Could you tell us a little bit about this? What change would you hope to inspire?
    a. Our project has us thinking about the merits of putting resources towards reducing WPI's carbon footprint verses improving the resiliency of vulnerable communities to the effects of climate change.
    b. Seeing as the master's program you are leading focuses on the issue of community resiliency, where do you see this balance?
2. What other projects have you worked on related to sustainability?
3. How do you think the Global Projects Program factors into the overall sustainability and environmental issues on campus?
4. Do you think the emissions cause by abroad travel are comparable to that of emissions produced on campus?
5. Where do you think the biggest sustainability focus should be in regards to the IQP and global projects as a whole?
6. What are your thoughts on carbon offsets?
7. Can you briefly explain the work you are doing with Gabriel Espinosa, as we have a meeting with him Friday?

Divest WPI

The team met with DivestWPI, an organization on campus pushing for WPI to divest from fossil fuels, to discuss some overlap in the respective projects. This conversation mainly revolved around interactions with WPI regarding policy changes.

Interview Questions

1. Could you tell us a bit about DivestWPI's mission and how it's gone so far?
2. What has your experience been making policy recommendations to WPI?
3. Who did you reach out to?
4. Please explain any obstacles you ran into in this process
5. Any insights for targeting WPI administration as an audience?

WPI Carbon Neutrality Project (Gabriel Espinosa)

The team met with Gabriel Espinosa, a student working on an on-campus emissions project, to gather his insight and expertise regarding his project and overlapping topics.

Interview Questions

1. Tell us about the carbon neutrality plan you have been working on.
    a. What is the timeline?
    b. Will there be a section dedicated to travel?
2. What actions would WPI take to become net zero? (carbon offsets, renewable energy, divestment, etc.)
    a. Opinion on carbon offsets?
        i. [If yes] are there any companies or organizations that you think are worth looking into?
    b. Are there other strategies besides carbon offsets you are considering?
3. Any suggestions for policy recommendations for the Global Projects Program? (share info about policy doc)

Appendix 4: Estimation Data Sources

Below are explanations of the sources and tools used by the team to make emissions estimations for the PRPC Emissions Case Study and PRPC IQP Emissions Calculator deliverables. These resources are categorized by air travel, living accommodations, and ground travel.

ICAO Carbon Emissions Calculator

Description:

> Carbon Emission Calculator developed by the International Civil Aviation Organization used to estimate the carbon emissions generated per person for an inputted flight route. Intended to be a tool that allows passengers to calculate the carbon emissions generated by their flight attributed to them.

Calculator: https://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx

Methodology: https://www.icao.int/environmental-protection/CarbonOffset/Documents/Methodology%20ICAO%20Carbon%20Calculator_v11-2018.pdf

Data Use:

- The ICAO Carbon Emissions Calculator was used to calculate air travel emissions for the PRPC Emissions Case Study. Survey data was plugged in and recorded into our spreadsheet.
- The ICAO Carbon Emissions Calculator Methodology was adapted and simplified by our team to create the air travel subcategory of the PRPC IQP Emissions Calculator.
- The fuel efficiency curves of 717-200, 737-900, and 787-8 aircraft used in the PRPC IQP Emissions Calculator sourced from the ICAO Fuel Consumption Table in Appendix C of the ICAO Methodology.
- The freight and load factors used in the PRPC IQP Emissions Calculator are sourced from the Load Factor By Route Group table in Appendix A of the ICAO Methodology.

Boing Airplane Characteristics for Airport Planning

Description:

Open-source data detailing Boeing aircraft characteristics.

Database: https://www.boeing.com/commercial/airports/plan_manuals.page

Data Use:

- Data for the number of seats in a full economy layout for each 717-200, 737-900, and 787-8 aircraft used in the PRPC IQP Emissions Calculator was sourced from each aircraft's respective database.

Open Flights Airports

Description:

Open-source database containing every major airport in the world. The database details each airport location (latitude and longitude).

Database: https://openflights.org/data.html#license

Data Use:

- Open Flights Airports Database was used to create the search function to determine the coordinate pairs of departure and arrival airports in the Air Travel Sub Calculator.

Hotel Carbon Measurement Initiative Tool

Description

A carbon emissions calculator developed by the Hotel Carbon Measurement Initiative to calculate the total and per room emissions of a hotel. Intended to be used as an industry tool by hotels to track carbon emissions and efficiency. Calculator tool and documentation can be found at the below link.

Website: https://sustainablehospitalityalliance.org/resource/hotel-carbon-measurement-initiative/

Data Use

- The team was able to generate an estimate for the carbon emissions generated per room per night at the Courtyard Marriott in Miramar (PRPC location) using input data received from the hotel's chief engineer. This per room per night estimate was used as a metric of living accommodation estimation in both the PRPC Emissions Case Study and Living Accommodations Sub Calculator.

US Department of Energy, Vehicles: Fuel Consumption and Efficiency

Description

Government database detailing the average national fuel efficiencies in miles per gallon-gasoline equivalent of major vehicle types.

Fuel Economy Database: https://afdc.energy.gov/data/10310

Per Passenger Fuel Economy Database: https://afdc.energy.gov/data/10311

Data Use

- Fuel efficiency data on vehicle categories of Car, Light Truck / Van, Paratransit Shuttle, and Transit Bus were used as a metric of project related ground travel estimation in both the PRPC Emissions Case Study and Ground Travel Sub Calculator.

US Environmental Protection Agency: Greenhouse Gas Equivalencies Calculator

Description

Calculator tool that provides various equivalencies for carbon emissions produced based on inputted fuel / energy metrics.

Calculator: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Data Use

- The ratio of kilograms CO_2 produced per gallon gasoline burned provided by the calculator was used as the emissions factor in the Case Study and Ground Travel Sub Calculator.

Appendix 5: Calculator Documentation

Two Excel calculator deliverables were developed by this IQP team, the PRPC IQP Carbon Emissions Calculator and the IQP Cohort Air Travel Emissions Calculator. These tools were made using three modular sub calculators, each representing one of the major categories of IQP emissions explored by this IQP: air travel, living accommodations, and ground travel. The sections below break down the two calculator deliverables, detailing user input, results, sub calculator dependencies and spreadsheet structure. The sub calculators used to build each major calculator are then discussed, explaining calculation logic and data sources.

PRPC IQP Carbon Emissions Calculator

The PRPC IQP Carbon Emissions Calculator is a tool developed for the Puerto Rico Project Center that uses student input to calculate an individualized estimate of the carbon emissions produced by their IQP trip. The calculator was developed in Excel to automate the methods of the PRPC Emissions Case Study conducted by this IQP and produces a total figure as the sum of air travel, living accommodations, and ground travel emissions estimates. The calculator is designed to require minimal user input to produce a student's estimate.

User Input

<u>Buttons</u>

Calculate: Displays the results to the calculator dashboard based on the user data entered. i.e., Attached macro updates the visualization table based on current data.

Reset: Suppresses inputted data so it is not displayed in the dashboard. i.e., Attached macro deletes estimate cell from the visualization table.

<u>1. Air Travel</u>

Connecting Airport Codes: The three letter airport codes of the user's round-trip journey to the PRPC. Separate each code using a comma and ensure airport codes are accurate. (Note: if mis-entered airport code is not included in the database latitude and longitude coordinates will return as 0,0. This will invalidate the estimation)

Seat Class: The seat class flown by the user. It is assumed that the entered value applies to all legs of the journey denoted in the "Connecting Airport Codes" field.

2. Accommodations

Boarding: The living accommodations provided to the user's IQP. Currently the only option available to be selected is the Courtyard Marriot in Miramar.

Nights Stayed: The number of nights stayed at the living accommodations on IQP.

Roommates: The number of roommates staying together, including the user.

3. Ground Travel

Vehicle: The vehicle types the user travelled in to commute to project sites.

Distance: The distances, in miles, that the user travelled in each respective vehicle type while commuting to their project site on an average week of IQP.

Input fields in the ground travel module are repeated three times to allow for calculations including up to three vehicle types.

Results

Estimation: Based on user and database input, the carbon emissions estimations for the user's air travel, living accommodations and ground travel are displayed in kilograms CO_2. The total of all three categories is displayed as the overall estimate for the emissions the user produced at the PRPC.

Data Visualization: The estimations calculated are displayed visually in a pie chart. The legend provided denotes the data displayed and a percentage breakdown.

Sub Calculator Dependencies

The PRPC IQP Carbon Emissions Calculator utilizes all three sub calculators: air travel, living accommodations, and ground travel. Reference the sub calculator sections included in this manual for information on the data and methodologies these calculations use.

Calculator Sheets

Below is a description of each sheet included in the calculator spreadsheet file and its contents.

PRPC IQP Emissions Calculator: Main page of the calculator. Sheet displays the user interface and results.

Authorship: Contains authorship and a link to our website. Our full IQP report can be downloaded there. Provides the IQP team's group email.

Visualization Table: Table referenced by the results display of the calculator. Values from each sub calculation section are pasted into the chart by macros attached to the calculate button and deleted by macros attached to the reset button on the main page.

Airport_LL: Open Flights Airport database. The version imported contains the name, city, country, three letter code, latitude, and longitude of almost all major airports in the world.

AT_Data: Air travel data and calculation sheet. Contains air travel sub calculator data tables and computation tables.

Data

Fuel Equation Data: Displays the raw data used to calculate fuel consumption equations for each of the three aircraft used by the sub calculator. Sourced from the ICAO methodology. Data table is explained in more detail in the air travel sub calculator section.

Equivalent Aircraft Table: Displays the breakdown of flight length into brackets and the aircraft assumed to approximate flights of this distance. Y-seat data and fuel consumption equations associated with each aircraft are also denoted.

*Note: These tables are for user reference only and data displayed is not directly referenced in the air travel sub calculator

Computation

Function Variables: Cells containing the freight, load and emissions factors used by the air travel sub calculator. Also, contains two seat class cells, premium and economy, referenced by the calculator input field.

*Note: Changing the values in this table will affect calculations.

User Input: Contains the cells linked to the "Connecting Airport Codes" and "Seat Class" input fields for air travel user input.

AT Computation Table: The rows of this table denote the legs of the user inputted flight route. The emissions calculation column of this table contains the user defined function getCO2Estimate( ) containing the calculations made by the air travel sub calculator (excluding seat class input). This function produces an estimate of the CO_2 produced by an individual's flight between the inputted airports (See Air Travel Sub Calculator). User data is mapped to this chart using a macro attached to the calculate button.

Computation Table Sum: Sum of the emissions calculation column of the AT Computation Table.

Air Travel Estimate: Finalized estimate for the individuals air travel emissions produced in kilograms CO_2. Factors in user inputted seat class (See Air Travel Sub Calculator).

LA_Data: Living accommodation data and calculation sheet.

Data

LA Database: Table containing one row: The kilograms of CO_2 produced per room per night by the Courtyard Marriott in Miramar. Data point sourced from Hotel Carbon Measurement Initiative Tool (See Living Accommodation Sub Calculator).

Computation

User Input: Contains the cells linked to the "Boarding", "Nights Stayed", and "Roommates" input fields for living accommodations user input.

LA Computation Database: This table pulls from user and database input to include all values needed by the living accommodation sub calculator formula. The individual estimate for living accommodations is provided by the right most column.

Living Accommodation Estimate: Finalized estimate of living accommodation emissions produced in kilograms CO_2.

GT_Data: Ground travel data and calculation sheet.

Data

GT Fuel Consumption Database: Table containing the fuel efficiencies of various modes of transportation used by the PRPC (See Ground Travel Sub Calculator).

Commute Table: Table containing distances to project site locations in miles

Computation:

User Input: Contains the cells linked to the "Vehicle" and "Distance" input fields for ground travel user input.

GT Computation Table: This table pulls from user and database input to include all values needed by the ground travel sub calculator formula for each of up to three entries. The individual estimate for each mode of transportation is provided by the right most column.

Weeks on IQP: Total number of project work weeks on IQP.

Ground Transportation Emissions Estimate: Finalized estimate of project related ground travel emissions produced in kilograms CO_2. Summation of the right most column of the GT Computation Table.

IQP Cohort Air Travel Carbon Emissions Calculator

User Input

Primary Flight Route Table: User inputs the three letter codes denoting the departure and arrival airports of each leg of a one-way route to their project site. Layovers are represented as multiple separate flights. This route should ideally be the most common sequence of flights taken. It can be assumed that Logan Airport (BOS) is the start point.

Cohort Information Table: User inputs the total amount of individuals in the cohort. This figure should include advisors and students.

Results

Individual Emissions: The round-trip emissions generated by one individual using the inputted flight path both ways.

Cohort Emissions: An estimation of the round-trip emissions generated by the entire cohort calculated by multiplying the individual emissions metric by the cohort size.

Sub Calculator Dependencies

The IQP Cohort Air Travel Carbon Emissions Calculator utilizes only the air travel sub calculator. Reference the air travel sub calculator section included in this manual for information on the data and methods used for these calculations.

Calculator Sheets

Below is a description of each sheet included in the calculator spreadsheet file and its contents.

IQP Cohort Air Travel Carbon Emissions Calculator: Main page of the calculator. Contains user input, results, and some in.

Authorship: Contains authorship and a link to our website. Our full IQP report can be downloaded there. Provides the IQP team's group email.

Visualization Table: Table referenced by the results display of the calculator. Values from each sub calculation section are pasted into the chart by macros attached to the calculate button and deleted by macros attached to the reset button on the main page.

Airport_LL: Open Flights Airport database. The version imported contains the name, city, country, three letter code, latitude, and longitude of almost all major airports in the world.

AT_Data: Air travel data and calculation sheet. Contains air travel sub calculator data tables and computation tables.

Data:

Fuel Equation Data: Displays the raw data used to calculate fuel consumption equations for each of the three aircraft used by the sub calculator. Sourced from the ICAO methodology. Data table is explained in more detail in the air travel sub calculator section.

Equivalent Aircraft Table: Displays the breakdown of flight length into brackets and the aircraft assumed to approximate flights of this distance. Y-seat data and fuel consumption equations associated with each aircraft are also denoted.

Regional Load/Freight Factor Table: Displays the contents of Load Factor by Route Group table from Appendix A of the ICAO Methodology. Allows users to customize the load and freight factors used in the calculator based on the regional flight group that best represents the journey from WPI to their project site.

*Note: These tables are for user reference only and data displayed is not directly referenced in the air travel sub calculator

Computation:

Function Variables: Cells containing the freight, load and emissions factors used by the air travel sub calculator.

*Note: Changing the values in this table will affect calculations.

Air Travel Sub Calculator

The air travel sub calculator was developed by the team to be a modular component of the two major spreadsheet calculators. The sub calculator is, except for the seat class calculation, entirely contained inside an excel user defined function: getCO2Estimate( ). This function takes two inputs, the three letter airport codes of departure and arrival for a given flight. To view the Visual Basic code in either major calculator, open the Developer Tab, Visual Basic, Modules, Module1.

The calculator was developed is based on the methodology provided for the International Civil Aviation Organization's Carbon Emissions Calculator. The sub calculator made by the team makes some assumptions to simplify this methodology and works with publicly available data.

Calculation Logic

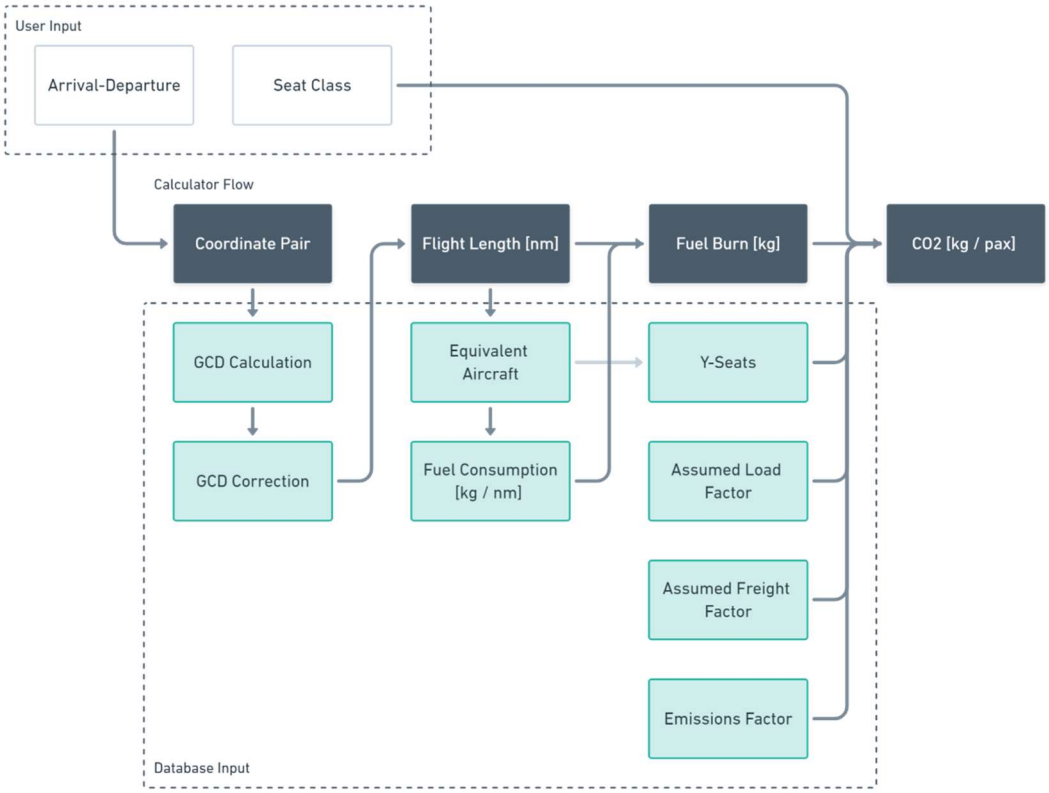


Figure 21: Air travel calculator logic flowchart

Figure 21 describes the logical flow of the air travel sub calculator. The graphic breaks down the calculator into three major steps between the four dark grey fields. User and database inputs are represented as white and green fields respectively.

Value Explanation:

Arrival – Departure: User inputs the three letter airport codes of their arrival and departure airports.

Coordinate Pair: The latitude and longitude coordinates of the departure and arrival airports. Source: Open Flights Airport Database

GCD Calculation: A great circle distance (GCD) in kilometers between the two pairs of coordinates is derived using the Haversine function. This calculation measures the direct route between the two coordinate pairs.

GCD Correction: A correction to the GCD made by adding a factor determined by the distance of the flight (See GCD Correction Table). This correction is intended to account for deviations from the direct route. Units are then converted from kilometers to nautical miles.
Source: ICAO Carbon Emissions Calculator Methodology

Flight Length: The corrected GCD in nautical miles and its corresponding flight length bracket: short, medium, or long haul (See Equivalent Aircraft Table).

Equivalent Aircraft: A common passenger aircraft model assumed based on flight length bracket [717-200 for short haul, 737-900 for medium haul, and 787-8 for long haul] (See Equivalent Aircraft Table).

Fuel Consumption: The equivalent aircraft's rate of fuel consumption per nautical mile traveled (See Equivalent Aircraft Table)
Source: ICAO Carbon Emissions Calculator Methodology

Fuel Burn [kg]: An estimation of the fuel burned based on flight length [nm] and fuel consumption.

Seat Class: User inputs their seat class (Premium or Economy). Estimations are made based on economy sized seats. Premium seating takes up around twice the space of economy seats. The calculator takes this into account by multiplying the baseline economy emissions by a flat rate of two to approximate premium emissions. (if Seat Class = Economy, then Seat Class = 1; if Seat Class = Premium, then Seat Class = 2)
Source: ICAO Carbon Emissions Calculator Methodology

Y Seats: The number of seats in an all-economy layout of the equivalent aircraft. (See Equivalent Aircraft Table).
Source: Boing Airplane Characteristics for Airport Planning

Assumed Load Factor: The percentage of aircraft seats assumed to be filled by passengers. Data sourced from the Load Factor by Route Group table in Appendix A of the ICAO Methodology. The IQP Cohort Air Travel Emissions Calculator's regional load factors are based on the average of North American load factors provided to avoid region specificity. The PRPC IQP Carbon Emissions Calculator uses the Central America/ Caribbean – North America route group load factor.
Source: ICAO Carbon Emissions Calculator Methodology

Assumed Freight Factor: The percentage of passenger weight to total cargo (passenger + freight). Data sourced from the Load Factor by Route Group table in Appendix A of the ICAO Methodology. The IQP Cohort Air Travel Emissions Calculator's regional freight factors are based on the average

of North American freight factors provided to avoid region specificity. The PRPC IQP Carbon Emissions Calculator uses the Central America/ Caribbean – North America route group freight factor.

Source: ICAO Carbon Emissions Calculator Methodology

Emissions Factor: Kilograms of CO_2 generated by burning 1 kilogram of aircraft fuel. (Emissions Factor = 3.16)

Source: ICAO Carbon Emissions Calculator Methodology

CO_2 [kg / pax]: The per person estimation of carbon emissions generated by the flight.

$$CO_2\left[\frac{kg}{pax}\right] = Emissions\ Factor * Seat\ Class * \left(\frac{Fuel\ Burn\ [kg] *\ Freight\ Factor}{Y\ Seats * Load\ Factor}\right)$$

Reference Tables

GCD [Kilometers]	Correction [Kilometers]
0-550	+50
550-5500	+100
+5500	+125

Figure 22: GCD correction table

Flight Dist. [nm]	Flight Bracket	Equivalent Aircraft	Y-Seats	Fuel Consumption (X = Flight Dist.)
0-800	Short Haul	717-200	117	-0.0004(X^2) + 6.3744(X) + 1107.5
800-2600	Medium Haul	737-900	189	-0.0002(X^2) + 6.8191(X) + 1470
+2600	Long Haul	787-8	359	-0.0001(X^2) + 11.155(X) + 2183.5

Figure 23: Equivalent aircraft table

Fuel Consumption Data [kg fuel/nm traveled]		Aircraft		
		717-200	737-900	787-8
Distance [nm]	125	1513	1782	2638
	250	3121	3641	5517
	500	4235	4839	7708
	750	5628	6533	10603
	1000	6989	8154	13421
	1500	9646	11255	18911
	2000	12209	14233	24276
	2500		17125	29557
	3000		19954	34779
	3500		22733	39954
	4000		25471	45093
	4500			50202
	5000			55286
	5500			60348
	6000			65392
	6500			70419
	7000			75433
	7500			81221
	8000			84439
	8500			

Figure 24: Fuel consumption derivation table

Data that the fuel consumption curves of 717-200, 737-900, and 787-8 aircraft used in the Air Travel Sub Calculator are sourced from the ICAO Fuel Consumption Table, Appendix C of the ICAO Methodology.

Data Sources

- ICAO Carbon Emissions Calculator
- Boeing Airplane Characteristics for Airport Planning
- Open Flights Airports

(See Appendix 4)

Living Accommodations Sub Calculator

The living accommodations sub calculator was developed by the team to be a modular component of the PRPC IQP Carbon Emissions Calculator. The calculator was developed based around having a metric for the emissions produced per night per room for the IQP living accommodations in question. The metric used currently was determined using the Hotel Carbon Measurement Initiative Tool with energy and floorplan data specific to the Courtyard Marriot in Miramar (PRPC living accommodations).

Calculation Logic

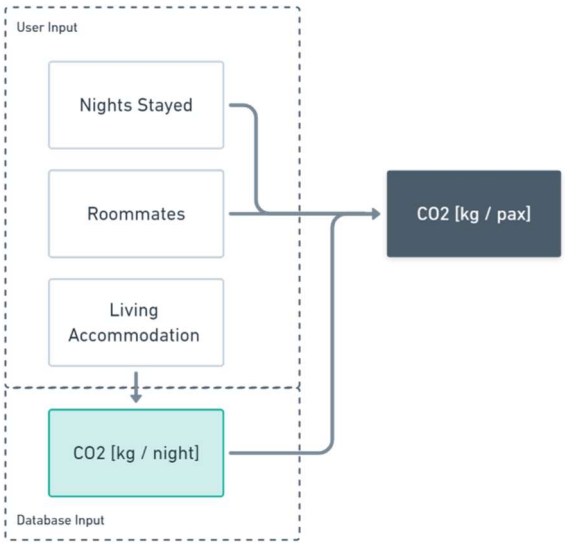


Figure 25: Living accommodation sub calculator logic flowchart

Figure 25 describes the logical flow of the living accommodation sub calculator. User and database inputs are represented as white and green fields respectively.

Value Explanation:

Nights Stayed: User inputs the number of nights spent on IQP

Roommates: User inputs the number of roommates they stayed with

Living Accommodation: User inputs the type of living accommodation

CO_2 [kg / night]: Amount of CO_2 produced by the inputted living accommodation per room per night. Estimation made based on data provided in the HCMI Data Entry Table.
Source: Hotel Carbon Measurement Initiative Tool

CO_2 [kg / pax]: Carbon emissions estimate for an individual student's IQP living accommodations.

$$CO_2\left[\frac{kg}{pax}\right] = \frac{CO_2\left[\frac{kg}{night}\right] * Nights\ Stayed}{Roommates}$$

Reference Tables

Courtyard Marriott Data	
Total Number of Guest Rooms	139
Area of one Guest Room (ft^2)	375
Area of Hallway (ft^2)	1252
Total Area of Guest Rooms and Corridors (ft^2)	64645
Area of Meeting Space (ft^2)	750
Occupancy Rate	80%
Total Number of Occupied Rooms per Year	40880
Electricity (kWh)	1432277
Gas (kWh)	277032
Oil (Liters)	0

Figure 26: HCMI data entry table

Total area of guest rooms and corridors is based on 10 hallways and 139 rooms

Occupied rooms per year is equal to the occupancy rate multiplied by the number of guest rooms multiplied by 365

Data Sources

- Hotel Carbon Measurement Initiative Tool

See Appendix 4

Ground Travel Sub Calculator

The ground travel sub calculator was developed by the team to be a modular component of the PRPC IQP Carbon Emissions Calculator. The calculator was developed based around passenger mile per gasoline-gallon equivalent metrics for various modes of transportation used at the PRPC. Using these metrics, it is possible to calculate individualized emission estimations for ground travel. The fuel efficiency data required was sourced from the US Department of Energy.

Calculation Logic

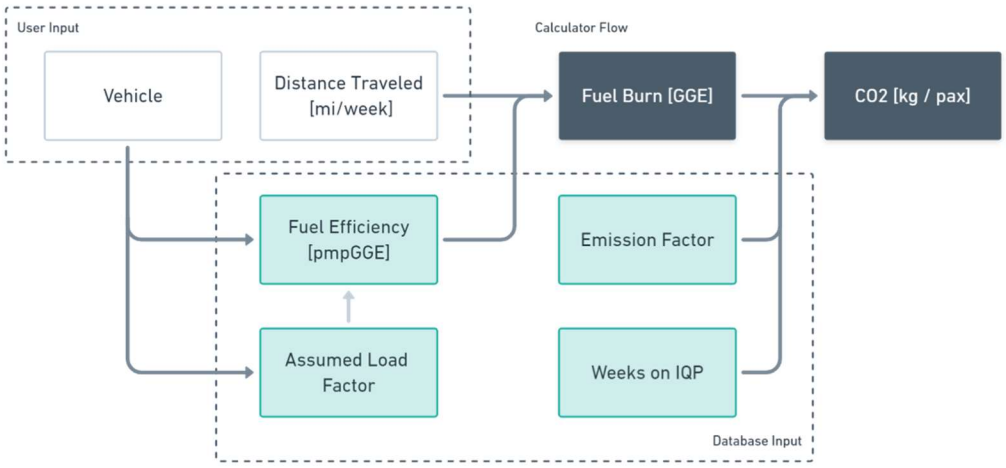


Figure 27: Ground travel sub calculator logic flowchart

Figure 27 describes the logical flow of the ground travel sub calculator. Calculator flow is represented by the dark fields while user and database inputs are represented as white and green fields respectively.

Value Explanation:

Vehicle: User inputted vehicle type.

Assumed Load Factor: Number of passengers assumed to be riding in the inputted vehicle type. (See Vehicle Fuel Efficiency Table). Assumptions were made based on an average IQP group size of 4 and average ridership data for public transportation.
Source: US Department of Energy, Vehicles: Fuel Consumption and Efficiency

Fuel Efficiency [pmpGGE]: The fuel efficiency of the specified vehicle in miles per gasoline-gallon equivalent (mpGGE) multiplied by the assumed passenger load factor. Yields units of passenger miles per gallon-gasoline equivalent (pmpGGE). (See Vehicle Fuel Efficiency Table)
Source: US Department of Energy, Vehicles: Fuel Consumption and Efficiency

Distance Traveled [mi / week]: User inputted distance for miles traveled in the specified vehicle per week.

Fuel Burn: Fuel burn in terms of gallons of gasoline equivalents per week that can be attributed to a single passenger.

$$Fuel\ Burn\ = \frac{Distance\ Traveled\ \left[\frac{mi}{week}\right]}{Fuel\ Efficiency\ [pmpGGE]}$$

Weeks on IQP: Database value denoting the number of weeks spent on IQP.
Weeks on IQP = 7

Emission Factor: Ratio of kilograms CO_2 generated to gasoline-gallon equivalents burned.
Emissions Factor = 8.9
Source: US EPA's Greenhouse Gas Equivalencies Calculator

CO_2 [kg / pax]: Carbon emissions estimate of the individualized ground travel emissions produced by the specified vehicle during IQP.

$$CO_2\ \left[\frac{kg}{pax}\right] = Emissions\ Factor * Weeks\ on\ IQP * Fuel\ Burn$$

Reference Tables

Vehicle Fuel Efficiency Table

Vehicle Type	Fuel Effieciency [mpGGE]	Load Factor	Fuel Efficiency [pmpGGE]
Car (Uber)	19.1	4	76.40
Van/Truck	13.1	4	52.40
Shuttle Bus (Small)	7.1	8	56.80
Transit Bus (Large)	3.3	8	26.40

Figure 28: Fuel efficiencies used during calculation

Car (Uber) and Van/Truck fuel efficiency are assumed to be 75% of fuel efficiencies provided by the data source originally (25.5) and (17.5) respectively. This assumption is to account for the fuel used to get to the passenger.

Data Sources

- US Department of Energy, Vehicles: Fuel Consumption and Efficiency
- US Environmental Protection Agency: Greenhouse Gas Equivalencies Calculator

(See Appendix 4)

Bibliography

Alden, N., Gomez, J., Shang, S. (2010). Developing an annual sustainability report for WPI. *Worcester Polytechnic Institute,* 1-68. http://web.wpi.edu/Pubs/E-project/Available/E-project-042610-180335/unrestricted/Developing_an_Annual_Sustainability_Report_for_WPI.pdf.

American Chemical Society. (2021). *What Is the Greenhouse Effect?* ACS Climate Science Toolkit.https://www.acs.org/content/acs/en/climatescience/climatesciencenarratives/what-is-the-greenhouse-effect.html

Andrews, J., Wake, C., Hargenrader, J., Janelle, W., Kaspari, J., Kelly, T., Kohler, A., O'Keefe, M., Pesci, S., Yates, C. (2021). WildCAP 2021: The University of New Hampshire's climate action plan. *University of New Hampshire,* 1-55. https://unh.app.box.com/s/he282os6o9l2k8s4o8dio53wefjaeuft

Brandeis, Thomas J; Woodall, Christopher W. (2008). Assessment of Forest Fuel Loadings in Puerto Rico. *Ambio, Vol. 37, Iss. 7/8,* 557-62.

https://www.proquest.com/docview/207666859/fulltextPDF/D4D5935C792449F6PQ/1?accountid=29120&forcedol=true.

Berchin, I. I., Grando, V. D. S., Marcon, G. A., Corseuil, L., Guerra, J. B. S. O. D. A. (2017). Strategies to promote sustainability in higher education institutions: A case study of a federal institute of higher education in Brazil. *International Journal of Sustainability in Higher Education, 18*(7), 1018-1038. https://doi.org/10.1108/IJSHE-06-2016-0102

Byrne, Jack. (2017). Campus sustainability hub: How Middlebury College achieved carbon neutrality.

Carbon Offset Guide. (n.d.). Carbon Offset Programs. *Carbon Offset Guide*. http://www.offsetguide.org/understanding-carbon-offsets/carbon-offset-programs/.

CARICOM. (2018). Regional Statement on the Intergovernmental Panel on Climate Change (IPCC) Special Report on the Impacts of Global Warming of 1.5 °C Above Pre-Industrial Levels (1.5 °C Special Report). https://caricom.org/regional-statement-on-the-intergovernmental-panel-on-climate-change-ipcc-special-report-on-the-impacts-of-global-warming-of-1-5-c-above-pre-industrial-levels-1-5-c-special-report/

NASA. (2021). Carbon Dioxide Concentration | NASA Global Climate Change. Climate Change: Vital Signs of the Planet. https://climate.nasa.gov/vital-signs/carbon-dioxide

CRS Insight. (2018). *Hurricanes Irma and Maria Impact on Caribbean Cou.pdf*.

https://sgp.fas.org/crs/row/IN10788.pdf

Duke Office of Sustainability. (2021). Carbon offset projects. *Duke University.* https://sustainability.duke.edu/offsets

Duke Office of Sustainability. (2020). Duke carbon offsets initiative: 2020 annual report. *Duke University*, 1-2. https://sustainability.duke.edu/sites/default/files/dcoi2020report.pdf

EIC. 4 Types of Carbon Offset Projects," December 2, 2020. https://www.eic.co.uk/4-types-of-carbon-offset-projects/.

Environmental Defense Fund. (2021). Extreme weather gets a boost from climate

change. https://www.edf.org/climate/climate-change-and-extreme-weather

Fain, S. J., McGinley, K., Gould, W., Parés, I. K., & Gonzalez, G. (2020). Cuba, Puerto Rico, and climate change: Shared challenges in agriculture, forestry, and opportunities for collaboration. (IITF-GTR-49; p. IITF-GTR-49). U.S. Department of Agriculture, Forest Service, International Institute of Tropical Forestry. https://doi.org/10.2737/IITF-GTR-49

Fern. (2016). What are carbon sinks? Fern: Making the EU work for People and Forests. https://www.fern.org/publications-insight/what-are-carbon-sinks-332/?gclid=EAIaIQobChMI97GArYf78gIVyNrICh0Vrg1_EAAYASAAEgKWevD_BwE

Franklin Environmental Center. (2021). Renewable Energy. *Middlebury College*. https://www.middlebury.edu/office/franklin-environmental-center/sustainability-action/renewable-energy

Gould, W.A., S.J. Fain, I.K. Pares, K. McGinley, A. Perry, and R.F. Steele. (2015). Caribbean Regional Climate Sub Hub Assessment of Climate Change Vulnerability and Adaptation and Mitigation Strategies. *United States Department of Agriculture.*

Guardian News and Media. (2011). *A complete guide to carbon offsetting*. The Guardian., from https://www.theguardian.com/environment/2011/sep/16/carbon-offset-projects-carbon-emissions.

Guardian News and Media. (2011). *What is emissions trading?* The Guardian, from https://www.theguardian.com/environment/2011/jul/05/what-is-emissions-trading.

Günther, Sebastian A., Thorsten Staake, Samuel Schöb, and Verena Tiefenbeck. "The Behavioral Response to a Corporate Carbon Offset Program: A Field Experiment on Adverse Effects and Mitigation Strategies." *Global Environmental Change* 64 (September 1, 2020): 102123. https://doi.org/10.1016/j.gloenvcha.2020.102123.

Hale, B. W. (2019). Understanding potential impacts from university-led educational travel. *International Journal of Sustainability in Higher Education, 20*(2), 245-263. https://doi.org/10.1108/IJSHE-09-2018-0163

Hale, B. W. (2019). Wisdom for traveling far: Making educational travel sustainable. *Sustainability, 11*(11), 1-12. https://doi.org/10.3390/su11113048

High Altitude Tropical Secondary Forests: A Competitive Carbon Sink? - ScienceDirect." Accessed October 15, 2021. https://www-sciencedirect-com.ezpv7-web-p-u01.wpi.edu/science/article/pii/S0378112701005357.

How-Carbon-Offsets-Work-Infographic-Web.Png (1600×1200). https://sustainabletravel.org/wp-content/uploads/How-Carbon-Offsets-Work-Infographic-Web.png.

International Civil Aviation Organization Environment. ICAO Carbon Emissions Calculator. *United Nations.* https://www.icao.int/environmental-protection/Carbonoffset/Pages/default.aspx

IPCC. (2018). Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai,

H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland.

Kelty, A. L., Dias, C. S., Cammarata, D. J., Cevallos, M. A. (2017). Sustainability at WPI: food waste management. *Worcester Polytechnic Institute,* 1-73. h https://core.ac.uk/download/pdf/212976561.pdf

Kolich, H. (2021). *What human activities increase carbon dioxide in the atmosphere?* HowStuffWorks Science., 2021, from https://science.howstuffworks.com/environmental/green-science/human-activities-increase-carbon-dioxide.htm.

Kollmuss, Anja, Clifford Polycarp, Michael Lazarus, Carrie Lee, Maurice LeFranc, Clifford Polycarp, Anja Kollmuss, Michael Lazarus, Carrie Lee, and Maurice Lefranc. *Handbook of Carbon Offset Programs: Trading Systems, Funds, Protocols and Standards*. London, UNITED STATES: Taylor & Francis Group, 2010. http://ebookcentral.proquest.com/lib/wpi/detail.action?docID=517190.

Main sources of carbon dioxide emissions: CO2 Human Emissions. Main sources of carbon dioxide emissions | CO2 Human Emissions. (n.d.). https://www.che-project.eu/news/main-sources-carbon-dioxide-emissions.

Mancinelli, L. J., Vega, D. J., Batchelder, N. E., Shingleton, P. C. (2018). Monitoring and presenting energy consumption to increase WPI sustainability efforts. *Worcester Polytechnic Institute.* 1-76. http://web.wpi.edu/Pubs/E-project/Available/E-project-050118-082750/unrestricted/EnergyDashboardMonitoring_Final.pdf

Méndez-Lázaro, P. A., Pérez-Cardona, C. M., Rodríguez, E., Martínez, O., Taboas, M., Bocanegra, A., & Méndez-Tejeda, R. (2018). Climate change, heat, and mortality in the tropical urban area of San Juan, Puerto Rico. *International Journal of Biometeorology*, *62*(5), 699–707. https://doi.org/10.1007/s00484-016-1291-z

Middlebury Study Abroad. (2021). Sustainability and study abroad. *Middlebury College*. https://www.middlebury.edu/office/study-abroad/sustainability-and-study-abroad

Myclimate. myclimate. (n.d.), from https://www.myclimate.org/information/faq/faq-detail/why-should-i-offset-my-emissions/?gclid=Cj0KCQjw1dGJBhD4ARIsANb6OdlWEdzelx_vXi0NEHZCqm5T9sFJefO2f7PJEn89GISAOlMzg1vElxgaAuGwEALw_wcB.

NOAA Climate.gov. (2018). *Hurricane Maria's devastation of Puerto Rico*. https://www.climate.gov/news-features/understanding-climate/hurricane-marias-devastation-puerto-rico

Nursey-Bray, M., Palmer, R., Meyer-Mclean, B., Wanner, T., Birzer, C. (2019). The fear of not flying: Achieving sustainable academic plane travel in higher education based on insights from South Australia. *Sustainability, 11*(9), 2694-2716. https://doi.org/10.3390/su11092694

Project MUSE - Private Governance in Developing Countries: Drivers of Voluntary Carbon Offset Programs. https://muse-jhu-edu.ezpv7-web-p-u01.wpi.edu/article/718521.

Puerto Rico Climate Change Council (PRCCC). 2013. Puerto Rico's State of the Climate 2010-2013: Assessing Puerto Rico's Social-Ecological Vulnerabilities in a Changing Climate. Puerto Rico Coastal Zone Management Program, Department of Natural and Environmental Resources, NOAA Office of Ocean and Coastal Resource Management. San Juan, PR.

Puig, R., Kilic, E., Navarro, A., Alberti, J., Chacon, L., Fullana-I-Palmer, P. (2017). Inventory analysis and carbon footprint of coastland-hotel services: A Spanish case study. *Science of the Total Environment,* 595, 244-254. http://dx.doi.org.org/10.1016/j.scitotenv.2017.03.245

Putz, Francis E., and Michelle A. Pinard. "Reduced-Impact Logging as a Carbon-Offset Method." *Conservation Biology* 7, no. 4 (1993): 755–57.

Serra, S. (2008). Advancing sustainability at WPI: the development of a comprehensive program for invesing in, promoting, and managing sustainable practices at wpi. *Worcester Polytechnic Institute.* 1-52. https://digital.wpi.edu/downloads/rv042t345

Silver, W. L., Ostertag, R., & Lugo, A. E. (2001, December 25). *The potential for carbon sequestration through reforestation of abandoned tropical agricultural and Pasture Lands*. Wiley Online Library. Retrieved October 4, 2021, from https://onlinelibrary.wiley.com/doi/full/10.1046/j.1526-100x.2000.80054.x.

Song, Lisa. (2019, May 22). *An Even More Inconvenient Truth: Why Carbon Credits For Forest Preservation May Be Worse Than Nothing.* ProPublica. https://features.propublica.org/brazil-carbon-offsets/inconvenient-truth-carbon-credits-dont-work-deforestation-redd-acre-cambodia/

Stojanovski, T. (2019). Urban form and mobility choices: Informing about sustainable travel alternatives,
carbon emissions and energy use from transportation in Swedish neighbourhoods. *Sustainability, 11*(2), 548-576. https://doi.org/10.3390/su11020548

Sustainability, Tracking, Assessment, and Rating System. (2012). Agnes Scott College: Tier2-1: Air travel emissions. *Association for the Advancement of Sustainability in Higher Education.* https://reports.aashe.org/institutions/agnes-scott-college-ga/report/2012-02-15/OP/climate/Tier2-1/

Sustainability, Tracking, Assessment, and Rating System. (2012). Dickinson College: OP-T2-1: Air travel emissions. *Association for the Advancement of Sustainability in Higher Education.* https://reports.aashe.org/institutions/dickinson-college-pa/report/2012-04-30/OP/climate/OP-T2-1/

Sustainability, Tracking, Assessment, and Rating System. (2021). Emory University: AC-5: Immersive Experience. *Association for the Advancement of Sustainability in Higher Education.* https://reports.aashe.org/institutions/emory-university-ga/report/2021-03-05/AC/curriculum/AC-5/

Sustainability, Tracking, Assessment, and Rating System. (2021). Keene State College: OP-1: Emissions inventory and disclosure. *Association for the Advancement of Sustainability in Higher Education.* https://reports.aashe.org/institutions/keene-state-college-nh/report/2021-03-04/OP/air-climate/OP-1/

Sustainability, Tracking, Assessment, and Rating System. (2013). University of California, Davis: OP-T2-1: Air travel emissions. *Association for the Advancement of Sustainability in Higher Education.* https://reports.aashe.org/institutions/university-of-california-davis-ca/report/2013-09-13/OP/climate/OP-T2-1/

Sustainability, Tracking, Assessment, and Rating System. (2011). University of New Hampshire: Tier2-1:

Air travel emissions. *Association for the Advancement of Sustainability in Higher Education.* https://reports.aashe.org/institutions/university-of-new-hampshire-nh/report/2011-08-02/OP/climate/Tier2-1/

Sustainable Hospitality Alliance. (2016). Hotel Carbon Measurement Initiative. *World Travel & Tourism Council.* https://sustainablehospitalityalliance.org/resource/hotel-carbon-measurement-initiative/

Sustainable Travel International. (2020). Carbon Footprint of Tourism. *Sustainable travel international.* https://sustainabletravel.org/issues/carbon-footprint-tourism/

Taylor, L. (2020). International Studies Office's commitment to sustainability and the green workplace program. *University of Virginia.* https://sustainability.virginia.edu/international-studies-offices-commitment-sustainability-and-green-workplace-program

Taylor, M. A., Clarke, L. A., Centella, A., Bezanilla, A., Stephenson, T. S., Jones, J. J., Campbell, J. D., Vichot, A., & Charlery, J. (2018). Future Caribbean Climates in a World of Rising Temperatures: The 1.5 vs 2.0 Dilemma. *Journal of Climate*, *31*(7), 2907–2926.

The Association of the Advancement of Sustainability in Higher Education. (2021). https://www.aashe.org/

The Potential for Carbon Sequestration Through Reforestation of Abandoned Tropical Agricultural and Pasture Lands - Silver - 2000 - Restoration Ecology - Wiley Online Library. https://onlinelibrary.wiley.com/doi/full/10.1046/j.1526-100x.2000.80054.x.

The Sustainability Tracking, Assessment, and Rating System. (2021). https://stars.aashe.org/

Tripoli, Lori. (2010). Sustainable travel: Policies, programs, and results: What corporations and higher education are – or should – doing. *Sustainability, (3)*5. 290-293. https://doi.org/10.1089/sus.2010.9745

Tufts Office of Sustainability. (2020). Green office certification checklist 1.4. *Tufts University,* 1-6. https://sustainability.tufts.edu/wp-content/uploads/Printable-Green-Office-Certification-Checklist-8.5x11-2020.pdf

Tufts Office of Sustainability. (2020). Green office certification program. *Tufts University.* https://sustainability.tufts.edu/sustainability-at-tufts/programs/green-office-certification/

UN Climate Change. (2021). Race to zero campaign. *2021 United Nations Framework Convention on Climate Change.* https://unfccc.int/climate-action/race-to-zero-campaign#eq-3

UNEP. "Carbon Offsets Are Not Our Get-out-of-Jail Free Card," June 10, 2019. http://www.unep.org/news-and-stories/story/carbon-offsets-are-not-our-get-out-jail-free-c

United States Environmental Protection Agency. (2016). *What Climate Change Means for Puerto Rico.pdf*. https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/climate-change-pr.pdf

University of Virginia Sustainability. (2021). About us: Plans and progress. *University of Virginia.* https://sustainability.virginia.edu/about-us/plans-progress

University of Virginia International Studies Office. (2021). Sustainability and education abroad. *University of Virginia.* https://educationabroad.virginia.edu/sustainability-education-abroad

University of Virginia Sustainability. (2020). University of Virginia Sustainability 2020-2030 Plan. University of Virginia, 1-20. https://sustainability.virginia.edu/sites/sustainability/files/202010/UVA_Sustainability_Plan_2020-2030-FINAL_0.pdf

USGCRP. (2018). *Climate Science Special Report* (pp. 1–470). U.S. Global Change Research Program, Washington, DC. Retrieved October 11, 2021, from https://science2017.globalchange.gov/chapter/2/

USGS. What Is Carbon Sequestration?" https://www.usgs.gov/faqs/what-carbon-sequestration?qt-news_science_products=0#qt-news_science_products.

Villoria-Sáez, Paola, Vivian W. Y. Tam, Mercedes del Río Merino, Carmen Viñas Arrebola, and Xiangyu Wang. "Effectiveness of Greenhouse-Gas Emission Trading Schemes Implementation: A Review on Legislations." *Journal of Cleaner Production* 127 (July 20, 2016): 49–58. https://doi.org/10.1016/j.jclepro.2016.03.148.

Ward, Jacob W., Michalek, Jeremy J., and Samaras, Constantine. (2021). Air Pollution, Greenhouse Gas, and Traffic Externality Benefits and Costs of Shifting Private Vehicle Travel to Ridesourcing Services. *Environmental Science & Technology, 55*(19). 13174-13185. https://pubs.acs.org/doi/full/10.1021/acs.est.1c01641#

What Human Activities Increase Carbon Dioxide in the Atmosphere? | HowStuffWorks. https://science.howstuffworks.com/environmental/green-science/human-activities-increase-carbon-dioxide.htm.

"Why Should I Offset My Emissions?" https://www.myclimate.org/information/faq/faq-detail/why-should-i-offset-my-emissions/?gclid=Cj0KCQjw1dGJBhD4ARIsANb6OdlWEdzelx_vXi0NEHZCqm5T9sFJefO2f7PJEn89GISAOlMzg1vElxgaAuGwEALw_wcB.

Willingness to Pay of Air Passengers for Carbon-Offset - ProQuest."

https://www.proquest.com/docview/1672890293?OpenUrlRefId=info:xri/sid:primo&accountid=29120.

WPI Office of Sustainability. (2020). WPI's sustainability plan – 2020-2025 overview. *Worcester Polytechnic Institute,* 1-2. https://www.wpi.edu/sites/default/files/docs/Offices/Sustainability/WPI_SustainabilityPlan_Overview_Post2%20%281%29.pdf.

WPI Office of Sustainability. (2010-2020). WPI sustainability report (various years). *Worcester Polytechnic Institute.* https://www.wpi.edu/offices/sustainability/reports-and-policies.

WPI Undergraduate Studies. (2021). Interactive qualifying project. *Worcester Polytechnic Institute. https://www.wpi.edu/academics/undergraduate/interactive-qualifying-project*