EGRS 451 Final Report
CAP: Transportation Group
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Reducing Emissions From Transportation At Lafayette

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Note:

This report represents the culmination of a semester long research project into finding methods to reduce emissions from the transportation sector at Lafayette College. The following sections will dive into the specific contexts related to the projects social, political, technical, and economic facets. From this report we look to build a lasting foundation for future sustainability projects both here at Lafayette College and at other schools and companies throughout the country. The motivation to pursue this project is based on the idea that all efforts related to climate change matter and by completing small initiatives such as our push to reduce emissions a snowball effect can lead to large scale change.

Introduction:

Background:

Up to 15 percent of global emissions are directly as a result of transportation processes using fossil fuels. (World Resources Institute, 2018) Looking to statistics based purely upon United States data it shows that roughly 29 percent of greenhouse gas emissions originate from the transportation sector. (United States Environmental Protection Agency, 2019) That is nearly twice the global percentage. This high percentage of greenhouse gas emissions makes the transportation sector one of the top overall contributors to climate change.

Climate change is a daunting task that lays right ahead of us and one person will not be able to overcome this obstacle on their own. Instead it will take a team effort from every person and group doing what they can to fight against this problem. An example of this is individual institutions of higher learning banding together and creating their own climate action plans to address their environmental footprint in the coming years. “In early 2008 Lafayette College President Dan Weiss signed the American College and University Presidents’ Climate

Commitment (ACUPCC). Through this commitment, the College pledged to take action to achieve carbon neutrality." (Lafayette College News, 2019)

In 2019 Lafayette College developed and passed an updated plan referring to it as the "Climate Action Plan 2.0". In this iteration of the climate action plan the school has pushed farther into how they plan to approach the next few years on the college's path to achieving carbon neutrality. The school has outlined a new commitment to achieving carbon neutrality by 2035 moving up the date by over a decade from the first climate action plan's approximations. (Lafayette College Office of Sustainability, 2019) A crucial piece of this plan is left rather underdeveloped from the rest of it. That piece is how the college plans on reducing the emissions from the transportation sector here at Lafayette College.

Figure 1: "Climate Action Plan 2.0", (Office of Sustainability, 2019)

Though underdeveloped, the college has outlined a concern for the levels of greenhouse gas emissions here at Lafayette within the transportation sector. While a popular area of study for other sustainability projects at the school is the Lafayette Shuttle or Lanta Bus Route our group chose to focus in on the college's everyday vehicle fleet. The current vehicle fleet here at Lafayette is large and has a mixture of different vehicles from varying years, manufactures, and models. Some general details and descriptions of the fleet are as follows. The fleet consists of a total of 109 licensed vehicles. The vehicles range in age from being purchased in the past 12 months up being purchased in the year 1995, roughly two and a half decades ago. It is great that we are able to take care of our vehicles and make them last but the emissions and fuel economy standards from the late 1990s are lacking in comparison to the environmental standards pushed forth in recent years. In addition, the brands making up the school fleet are american companies such as Ford and GMC, known for having worse environmental standards than their foreign specifically asian counterparts such as Nissan and Toyota. In addition, the models of vehicles within the Lafayette Fleet are primarily trucks, vans, and SUVs which large sizes and heavy weights often parallel poor fuel economy. Over one third of the 109 vehicles within the fleet are 10 plus years old. Almost all of these vehicles [37 total] can be classified as reaching the end of their economic useful life in 2020. Replacing all 109 vehicles at one time is unrealistic and most

likely irresponsible as the school has not yet built out large plans for how to fully integrate electric vehicles. But starting with a smaller portion of the 37 vehicles could be an appropriate "test case" for the school to see the positive environmental impacts of the switch to electric and hybrid electric vehicles.

How are we going to do it?

Our teams' goal was to explore the implementation of a system that truly reduces the emissions from the transportation sector opposed to just shifting them to another location. For this reason, the basic idea of purchasing electric cars was not a sufficient goal to reach. Instead our team felt as if our real goal throughout this project was to build a closed system that has no reliance on fossil fuels. With no reliance on fossil fuels we would have reduced emissions seemingly instantly. We pursued this through exploring methods of alternative energy production that can sustainably power car chargers which in turn can charge electric vehicles with clean energy.

Our solution is the designing and implementation of a system that utilizes a three-pronged approach to emissions reduction. First, we plan to use alternative energy production in the form of a solar canopy to provide clean renewable energy to the project. Second, we plan to implement car chargers that can act as a method to transfer the clean energy from production in the solar canopy to the action of charging vehicles. Therefore, the third and final "prong" of our plan is to implement electric vehicles to ensure less emissions are produced from the act of driving.

Challenges:

As a group we face numerous challenges with this project. As previously mentioned, our project is a multipronged approach combining solar canopies, electric charging stations, and electric vehicles to create a system with no emissions from fossil fuels. Each part of our system is a complex solution in its own right and comes with a hefty price tag. The project is an expensive endeavor and so we must find reasons to justify the cost. Our second challenge is to find individuals and groups to pass our work off to now that we have reached the end of our time working on this project. Similarly, the third challenge that has constantly been on our radar is how we will stand to develop guidelines and legislation for future efforts within this subject field. We want to ensure other groups such as the office of sustainability are able to pick up where we left off and continue to work in this important field.

Overcoming these challenges is an ongoing difficult task but with appropriate planning and communication we believe they are all in the realm of possibility. To address the first challenge of high costs, the key is going to be research and data analysis. Often the way numbers and costs are presented have an impact on how they are received. Our project is going to be expensive and that is inevitable but, through research and analysis we can look at the possible

benefits of the project through tax credits and grants which in turn will reduce the cost to a more manageable level.The other challenges are also pivotal in the continued work on the project. It is important to find consulting parties and or professionals who can work with us in order to create plans and legislation that fit into the mold of the project that we have begun envisioning. These parties are not necessarily expensive consulting firms but rather individuals and groups that are present here at Lafayette. Professors are a resource that we look to include in this process as we try and piece together how this technological system of electric cars, charging stations, and solar canopies will function in practice. In addition to that possibly the most important part of this project is to lay a foundation for similar efforts in sustainability going forward. This project can serve as a case study and baseline for developing further initiatives to increase the sustainability of our campus through systems such as emissions reduction and renewable energy.

The FIVE sections of focus:

Our report will begin with a look at the varying social contexts that will influence the direction and overall scope of our project. These contexts explore several pivotal factors to the success of the project including social dynamics and the stakeholders associated with the project. Our group's solutions look at not only the idea of electric cars and plug in hybrids to replace the college fleet but also more importantly complicated technologies associated with renewable energies and how to turn those into viable charging energies. This combination of solutions has the possibility to impact the greater Lafayette community and surrounding areas through access to clean charging stations that reduce the environmental impact of fossil fuel emissions. The administration will be the main stakeholder throughout this project as they have set the groundwork in the Climate Action Plan 2.0 for what they wish to see as far as emissions reductions from the transportation sector in coming years. This dedication and commitment from the school has allowed us the opportunity to focus and support our work with direct evidence from the school that what we are working on is a priority here at Lafayette.

Following our analysis of the social contexts throughout our project we turned to the political and policy based contexts next. In this section we look more closely at the roles that our major stakeholders play in electrifying the fleet of college owned vehicles as well as taking a further dive into the existing policies outlined within the colleges Climate Action Plan 2.0. In order to get a grasp on how the college and our greater society has reached the point we are currently in we must analyze methods that have laid the foundation for our current efforts. Throughout our project we are looking to enhance the conversation about electric vehicles and alternative energy charging station on campus hoping to redefine and build out specifics on how the college can continue to reduce emissions and make the transportation sector more sustainable for years to come.

The section following the political portion of our report will be the economic context analysis. There will be two distinct sections in this portion. The first will analyze the non market

value economic impacts the project holds. These could include a better reputation and higher ranking among the elite liberal arts institutions. The second part is more focused along the lines of tangible numerical figures. This is where we will break down the numbers and look at the financial feasibility of this project. Electric vehicles, plug in hybrids, charging stations, and alternative energies such as solar carports all come with a price tag; therefore, it is crucial we lay a foundational understanding of what the economic impact of this project would be for the school. This context will include more than just price tags though because the implementation of these new technological systems come with certain tax benefits such as credits and write offs from both federal and state governments which need to be taken into account.

Analyzing the technical components of this project cannot be overlooked as it will play a key role in many of the decisions as far as what vehicles are the most suitable replacements, what charging stations we should implement, and how to generate clean renewable energy for usage by the charging stations. There will be significant technical analysis in order to ensure that the whole system is able to work interchangeably. We are also studying the technical contexts in relation to how we can possibly quantify the total amount of emissions reduction that electric vehicles will contribute to the college. Implementing charging stations and solar canopies for charging will require technical knowledge and consultations that will be explained in depth farther along in the report.

The environmental portion of this report is an all-encompassing part that cannot be overlooked in any way. Our whole basis for this project is to reduce greenhouse gas emissions from the vehicle fleet here at Lafayette College in order to make the schools transportation sector more sustainable in the future. Throughout our research we have found that emissions are a leading cause of manmade climate change and so our project is directly related to the expectations regarding Lafayette's sustainability in the future. One piece of our project that we are analyzing the most throughout our environmental context is our focus on solar power to provide energy for the charging stations on campus. If we implement charging stations that are simply connected to the electric grid, we are doing very little in the grand scheme of reducing emissions. We are simply shifting the location of the emissions instead of truly reducing their occurence. This context will allow us to ensure our project is being completed in a way that is true to its idea of having a positive environmental impact.

Social Context:

This Engineering Studies capstone project looked to significantly reduce carbon emissions from Lafayette College's transportation sector. This project is informed and given shaped by several social contexts that have affected our decision-making and affect the success of this initiative. The first of which and the most pertinent being climate change.

Edmond Mathez, similar to many other researchers, argues that the Earth's steadily rising climate and the accumulation of carbon dioxide (CO2) and other greenhouse gases are a direct consequence of burning fossil fuels. Furthermore, he states that the research is overwhelming that this accumulation of greenhouse gases is the cause of warming. "These statements are the facts of climate change." (Mathez & Smerdon, 2018). Earth's rising climate and the negative implications it has on the Earth's ecosystem has catalyzed the global initiative to reverse these effects. This global initiative can be seen in the creation of the Intergovernmental Panel on Climate Change (IPCC). The official website for the IPCC, reports "The IPCC was created to provide policymakers with regular scientific assessments on climate change, its implications and potential future risks, as well as to put forward adaptation and mitigation options" (The Intergovernmental Panel on Climate Change). The IPCC has budgeted about 1.5 degrees Celsius of global warming before the effects of climate change are irreversible, listing an increased frequency and magnitude of floods and droughts and "risks of local species losses and, consequently, risks of extinction are much less in a 1.5°C versus a 2°C warmer world." as potential consequences of exceeding that budget. (Summary for Policymakers, 2018)

In addition to calculating and mitigating risks, the IPCC also provides ways to prevent these consequences. The Panel finds the key to limiting warming and staying within this budget lies within greenhouse gas emissions, "Limiting warming to 1.5°C depends on greenhouse gas (GHG) emission over the next decades, where lower GHG emissions in 2030 lead to a higher chance of keeping peak warming to 1.5°C." (Summary for Policymakers, 2018). This finding supports the gradual transition to vehicles that use alternative fueling methods from those that use fossil fuels.

The world started to seriously consider when automakers, including General Motors, began exploring options for alternative fuel vehicles in 1973. Sebring Vanguard's CitiCar, the only successful electric car at the time, had a range of only fifty to sixty miles. Despite this advancement, interest in electric vehicles subsided until 1992, when new federal and state regulations created a "renewed interest in electric vehicles." As a result, Toyota designed and released the first hybrid to be mass-produced, the Prius in 2000 for around $20,000. For context, $20,000 in January 2000 has the saying buying power as about $30,000 today. ("Timeline: History of the Electric Car") While the vehicle had good reviews, the price of the vehicle posed some concerns around consumers. One may assume that many did not see the benefit of purchasing an electric car when a gasoline-powered car serves the same purpose and has lower costs. However, in 2013, as concerns of climate change became more prevalent and the United States government, specifically the Department of Energy, began to make investments, the cost of the battery dropped by 50 percent in four years. ("Timeline: History of the Electric Car") The battery is generally the most expensive part of an electric vehicle and this price drop allowed for more affordable electric vehicles. As of today, there are 23 plug-in electric vehicles and 36 hybrid models available for purchase. Furthermore, according to energy.gov, if all light-duty

vehicles in the United States transition to an electric alternative, we could lower carbon pollution from the transportation sector by as much as 20 percent. (“Timeline: History of the Electric Car”)

Lafayette College is committed to sustainable solutions and promoting a sustainable lifestyle. In 2011, the College enacted the Climate Action Plan that worked to reduce greenhouse gas emissions by improving ride-sharing systems, implementing GPS tracking on Lafayette shuttles, allowing student users to track Lafayette shuttle services on, and around, College Hill, organizing a Student Government transportation subcommittee, and introducing a U-Haul carshare program. While implementing these programs were steps taken in the right direction, Lafayette College decision-makers recognized how much has changed since the implementation of this Plan in 2011 and realized the opportunity that Lafayette had to do more. As a result, Lafayette College published the Climate Action Plan 2.0 in 2019, which offers detailed and active methods to achieve the College’s goal of carbon neutrality by 2035. According to Lafayette College’s Climate Action Plan 2.0, “The campus can reduce transportation emissions through behavior changes, fuel-switching, increased vehicle efficiency, and carbon offsets. Each emissions source will be addressed through appropriate strategies” (Lafayette College of Sustainability, 2019).

The price of electric vehicles has significantly dropped since the mass production of the Prius in 2000. According to Kelley’s Blue Book, a new 2019 Toyota Prius starts at $24,700, which is about $6,000 less than the adjusted $30,000 cost of the 2000 Prius. This price drop makes Lafayette’s transition to an all-electric fleet more feasible. Historically, almost all of Lafayette College’s transportation fleet has consisted of vehicles powered by fossil fuels and emit carbon. One can conclude that the availability of a more affordable electric vehicle, along with the global initiative to limit carbon emissions, has allowed Lafayette College this opportunity to address its contributions to carbon emissions in this way.

Additionally, Lafayette College underlines its commitment to sustainability on campus and fostering a community committed to sustainable living when advertising to potential students. However, many initiatives geared towards sustainable living are not as noticeable as you walk across the Lafayette campus. One of Lafayette’s most marketable attractions, LaFarm, is located off-campus at the Metzgar Fields Complex. The initiatives that are easily seen, such as an increase in the number of mixed recycling bins on campus and the implementation of initiatives similar to Green Move-Out, do not stand out as something that separates Lafayette from other institutions. It would behoove Lafayette College decision-makers to consider our proposal as an opportunity to achieve their goal of carbon neutrality, as well as an illustration of their commitment to sustainable living.

Several colleges in the United States have implemented the use of electric vehicles or a solar canopy on campus. In 2016, Colorado State University has obtained four new Nissan LEAFs for

use around campus. Two of these electric vehicles can be checked out by Housing and Dining Services staff to attend meetings, run University errands, or complete deliveries. The other two electric vehicles are intended for use by Facilities Management staff to travel between the three parts of campus and attend meetings. (Miyamoto, 2017) The Colorado State University Nissan Leafs can be found in Image 1, below.

Figure 2: Colorado State University Nissan LEAF, (Miyamoto, 2017)

According to Mass Transit Magazine, the University of California, Irvine (UCI) is the first college in the nation to have converted to an all-electric bus fleet. In 2017, UCI acquired twenty electric buses in hopes of achieving their goal of emitting net-zero greenhouse gas emissions from buildings and vehicles by 2025. (Motors, 2017)

While Lafayette College is not looking to mimic these initiatives from Colorado State University and UCI completely, it shows that colleges around the United States are already undergoing transitions to create a more sustainable campus. In order for Lafayette College to continue marketing a culture of sustainability on campus, entities of this culture must be more visible as they are at UCI and Colorado State University. Furthermore, these other projects show that a fleet consisting of electric vehicles is not a completely foreign idea and can also serve as a reference to Lafayette College in trying to complete our proposed project.

We also recognize the regular concern with electric vehicles is that using electricity from the grid as a means to charge these vehicles is still contributing to carbon emissions, Therefore, simply transitioning to an all-electric fleet limits us in pursuing carbon neutrality. This is why we propose utilizing renewable energy, such as solar energy, to power the new electric fleet will have greater contributions to the College's goal of reducing greenhouse gas emissions from Lafayette's transportation sector.

Additionally, we must acknowledge Lafayette's split campus. Lafayette College owns and utilizes the Downtown Williams Arts Campus and Metzgar Fields in Forks Township. While

they are considered crucial parts of the Lafayette College identity, these facilities are considerably separated from Lafayette's main campus. Metzgar, itself, is not within walking distance and the only direct route from the main campus to the Arts campus is a set of steep and dangerous steps that pose a danger to students trying to use them, especially when it begins to snow. As a result, Lafayette College has implemented public transportation systems to transport students between these facilities and the main campus. We are confident that our proposal will not only align with the Climate Action 2.0, but also align with the sentiment of the Lafayette College's master plan, strengthening the identity of the campus. (Lafayette College Master Plan, 2009)

Nationally, the transportation sector only accounts for about 29 percent of total United States greenhouse gas emissions. ("Carbon Pollution from Transportation", 2019) At Lafayette College, only three percent of the College's total emissions are contributed to the transportation sector. (Lafayette College Office of Sustainability, 2019) This figure stems from emissions coming from Lafayette College-owned vehicles. It does not take into account emissions from commuters, student/faculty vehicles, or transportation to, and from, study abroad programs. This is an important distinction to recognize, as it altered our approach to this project. When first investigating the problem on campus and the actions that we wanted to implement, we had to consider the initial scope of the project. We found we did not have sufficient time to attempt to mitigate student driving habits and the emissions used when traveling to study abroad programs. As a result, decided to redirect the scope of our project to align with that of the Climate Action 2.0, which is solely addressing greenhouse gas emissions from the Lafayette College transportation fleet. However, we are hopeful that a more visible effort on campus will encourage students to be mindful of their carbon footprint, specifically how it is affected by their driving tendencies.

Political and Policy Context:

Both smaller communities such as Lafayette College and influential nations are addressing the problems of climate change. "Greenhouse gas (GHG) emissions from transportation account for about 29 percent of total U.S. greenhouse gas emissions, making it the largest contributor of U.S. GHG emissions. Between 1990 and 2017, GHG emissions in the transportation sector increased more in absolute terms than any other sector" (EPA 1). The transportation sector needs a major overhaul in order for the United States to reduce its carbon emissions. It has made some strides, setting GHG emission and renewable energy standards in an effort to reduce these harmful emissions. The Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007 helped create a foundation to build from when setting standards for transportation (Alternative Fuel Data Center 1). These acts were essential for the United States to solidify its own identity as one of the world's most influential and progressive countries. This ideology, the desire for a positive perception from others as well as shifting values helped create and establish more environmentally conscious federal regulations. These

motives are very similar to those held by Lafayette College, prompting stakeholders to pass the Climate Action Plan as it tries to achieve carbon neutrality.

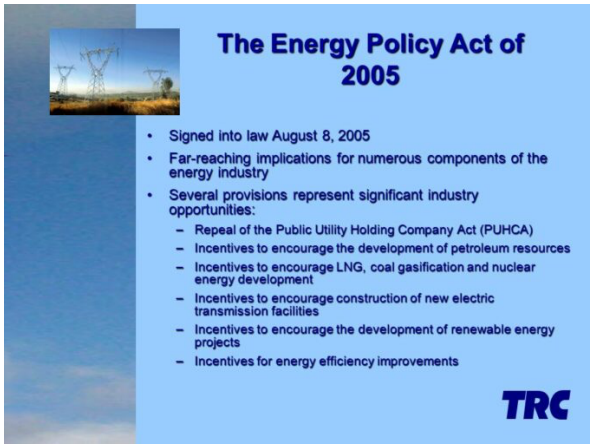

Figure 3: "Energy Policy Act of 2005", (US EPA, 2019)

Higher emphasis put on reducing emissions also led to more extensive research including the Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2017. This national inventory is under the United Nations Framework Convention on Climate Change, an environmental treaty adopted in 1992 to make a more conscious effort to better understand the impact emissions has on the environment (EPA). This program conducted extensive research and found that 29% of GHG emissions are from transportation and light-duty vehicles account for 59% of those emissions.

Lafayette College is a private institution that has an end goal of providing an enlightening educational experience for students while also trying to make as much money as possible. This Climate Action Plan is part of that mission. If Lafayette College wants to be considered a top-tier liberal arts college, it needs to be at the frontier of pressing issues and presenting itself in the best light possible. The United States government provided a framework for environmentally conscious actions to take priority to cost to an extent. This encouraged institutions like Lafayette College to take the steps necessary to stay attack climate change. If other colleges make a conscientious effort to reduce their emissions and Lafayette does not act accordingly, it would lower the quality of applicants. Public perception is a massive component to decision-making. Institutions are competing with one another to have the most technologically advanced, safest, environmentally friendly, beautiful campus to recruit the highest possible talent.

As part of the Climate Action Plan 2.0, Lafayette College committed to achieving carbon neutrality by 2035. The original Climate Action Plan focused on providing shared transportation to students through the LCAT system of buses and two U-Haul cars available at Sullivan Parking Deck. These implementations helped contribute to a 20% reduction in emissions on campus, however, more steps need to be taken to meet the carbon neutral goals set by the college.

(Lafayette College Office of Sustainability, 2019) The Climate Action Plan 2.0 does provide a general overview for achieving these future goals, but there are countless political factors that still need to be addressed. There needs to be a collaborative effort between the Board of Trustees, Office of Sustainability, Financial Planning and Capital Budget Department, and external providers to steer Lafayette towards a carbon neutral environment.

The department that plays a crucial role in dictating the implementation of transportation related sustainability efforts is the Financial Planning and Capital Budget Department. This department is responsible for providing financial analysis and advice to decisions-makers at Lafayette for long-term planning. This includes financing, capital management, and risk management to support the Board of Trustees with certain decisions. (Finance and Administration, 2019) This group will conduct financial analyses of different emission reduction alternatives to determine the most feasible options. Further explanation will be provided in the economic context section, but this includes evaluating costs and risks associated with replacing the current fleet of Lafayette owned vehicles with more fuel-efficient options, different charging stations, and solar canopies to power the charging stations. The Financial Planning and Capital Budget Department would then relay their findings to the Board of Trustees to better educate them on potential options.

Another key player in this process is the Office of Sustainability. This department provides a similar role to the Financial Planning and Capital Budget Department, acting as a resource to the Board of Trustees and others in need of sustainable information. The Office of Sustainability has specialized knowledge regarding Lafayette's current transportation emissions, efforts taken to approach carbon neutrality, steps taken at other institutions that can be applied to Lafayette, etc. For instance, Nick DeSalvo provided information regarding electric vehicles used at DeSales University. They purchased an electric vehicle to replace one of their campus police vehicles. All of the officers responded positively to the switch, proving that a transition to more fuel-efficient vehicles is realistic. Although most emissions results from heating and water on campus, reducing current transportation emissions could be a crucial component to achieving the goals set in the Climate Action Plan 2.0.

The Financial Planning and Capital Budgeting Department along with the Office of Sustainability should not and therefore will not be doing this work alone. As Engineering Studies students, we have taken classes in the economics and finances of these large financial projects as well as we have studied the process of sustainability initiatives through courses on public policies and sustainable solutions. By pulling from this preexisting coursework our group and future groups will play pivotal roles in solving the puzzle that is reducing carbon emissions from the school's vehicle fleet and creating legislation that will continue to promote sustainability practices in transportation for years to come. The combination of efforts from both the students and the administration is what is going to help this project succeed. There are different perspectives that come with being in a student role versus a professional role and bringing those

together is what has the power to make this project a success. At the end of the day the college is here to educate students and positively benefit the communities surrounding it.

The Board of Trustees is one of the most crucial players in the implementation process since they would be the ones making decisions regarding different sustainable transportation alternatives. The Board consists of 35 members from a variety of professional backgrounds that help shape the future of Lafayette. Each of the previous departments help provide further insight into sustainability discussions by the Board of Directors. The board understands the importance of the updated Climate Action Plan and taking the necessary steps to achieve carbon neutrality. However, the board also recognizes that cost is always a factor. This is where the Financial Planning and Capital Budget Department and the Office of Sustainability provide their findings regarding potential decreases in emissions and costs associated with each option. The first decisions regarding replacing the vehicles in the current fleet with more fuel-efficient options. They will then need to discuss implementing more charging stations on campus. There are currently 6 stations located in Markle Hall parking deck, Watson Hall parking lot, and at 901 Bushkill Drive. They will need to understand different station power levels and figure out the optimal option to implement on campus. The last component that the Board of Trustees will need to vote on is the power source used to power the charging stations. The board needs to discuss these decisions with some of the other departments to understand their feasibility.

Another crucial component that could enable Lafayette College to become more sustainable us the issuance of grants. In 2018, Northampton County was awarded $30,000 in grant funding for the installation of three Level 2 charging stations. (69 News, 2019) These Level 2 charging stations can charge two vehicles at a time and are located at the Department of Human Services in Bethlehem and the parking deck at the Courthouse in Easton. The grant was provided by Driving PA Forward, an initiative started by Governor Wolf's Administration and the DEP to increase air quality in Pennsylvania. State and federal governments understand the importance of fuel-efficient modes of transportation and are taking climate change seriously. This program will provide $7.7 million to help install these charging stations for public use. (Pennsylvania Department of Environmental Protection, 2018) If Lafayette College is serious about increasing the amount of charging stations on campus, they will need to apply for grants such as those driven by this program.

There are also countless federal and state financial incentives available to ease the significant initial costs associated with each facet of this project. This includes one provided by the Department of Community and Economic Development through the High-Performance Building Incentives Program. This program provides grants up to 10% of the project cost which would help reduce the massive initial costs associated with the installation of solar panels (Solar Insure, 2019). Another incentive that would decrease the significant solar canopy costs is the Solar Investment Tax Credit. The ITC was enacted in 2006 and provides a 30% tax credit on residential and commercial solar systems (Solar Energy Industries Association 1). Either of these

options would make a solar canopy more affordable for Lafayette College and hopefully persuade stakeholders to incorporate solar canopies on campus.

There is also the Electric Vehicle Supply Equipment Rebate that reimburses institutions $5,000 or up to 80% of the total project costs for the acquisition, installation, maintenance, and operation of Level 2 charging stations (EVSE 1). Another state incentive that is directed towards the purchase of more environmentally friendly vehicles is the Alternative Fuels Incentives Grant Program. This program provides financial assistance through incremental cost expenses and the cost of purchase associated with bi-fuel, duel-fuel, or dedicated vehicles (AFIG Program 1). These are just some of the many programs with funds dedicated to incentivizing more sustainable energy sources. Lafayette needs to apply for different grants, reducing costs incurred. This decrease in initial costs will result in less resources getting redirected from other parts of the college. The more grants Lafayette receives, the more willing the Board of Trustees and other stakeholders will be to support the implementation of solar panels as the main energy source for the electric charging stations.

Figure 4: "Charging Station Available for EVSE Rebate", (EVSE, 1)

The Climate Action Plan 2.0 provides a general base for us to start our emissions reduction efforts. Beyond that the plan lacks a complete vision and depth for us to follow. A crucial part to our political context is defining this section of the plan further for decision-makers to use when addressing Lafayette's transportation emissions. Defining the future guidelines of the Climate Action Plan 2.0 as it pertains to emissions from the transportation sector will unlock new opportunities for students and faculty to explore other options for change once we lay the groundwork of our project. Right now the only guidance that we have is that the college has stated they wish for in the immediate future for faculty and students to invest time and effort into investigating the emissions coming from the transportation sector and then to identify possible technologies and processes for reducing emissions. Beyond that there is no true framework to this area of the Climate Action Plan. The authors of the plan leave it rather open ended stating it will be important to continually address the situation and possible solutions in the near future through identifying areas of potential. (Lafayette College Office of Sustainability, 2019) Our team plans to give the office of sustainability and the college our research in hopes they can take it and implement it in the plan so that new groups who approach this in the future have a place to start instead of only having the option to create something out of nothing.

Climate change is a large scale problem with an inherently complicated political atmosphere when it comes to finding solutions. Often people try to address climate change from the top of the problem down and are soon overwhelmed by the seemingly insurmountable odds stacked against them. After all, how many people alone know how to stop megatons of CO2 from being emitted each year? Few people, groups, and larger communities fail to ever consider constructing a Climate Action Plan similar to Lafayette's. Many feel in the end it will result in the outcome that nothing can be done to completely solve the issue of climate change and therefore anything they d would only end up negligible. Our project here at Lafayette and others just like it stand to change this stigma. One school such as Lafayette that has invested the time and energy into changing its policies and choices can act as a catalyst to its surrounding communities to spread change and sustainable practices far and wide. This wave of change can wash over entire counties, states, and eventually nations. So instead of just 37 cars turning to electric in a college fleet it is hundreds upon thousands of cars making the switch to more sustainable emissions. That is the difference between scratching the surface and starting to make a real dent in the problem. The key to this whole movement lies within a single baseline example or case study to work from. Our project can be the case study that other administrations, governments, and councils look to as an example of initiating real tangible change in the face of climate change and continuing to hold their administration and community to higher levels of sustainability.

Technical Context:

The technical context for our group was especially important to create a system that was effective in achieving our goal of emissions reduction. We needed to create a system that was sustainable and actively supported the reduction of emissions on our campus without shifting the location of the emissions. We focused on the three major components of sustainable energy production, the transfer of energy from production to a vehicle, and finally the vehicle itself. For our project these 3 components take the form of solar carports, electric car chargers, and a fleet of electric / plug in hybrid vehicles. These 3 distinct pieces ensure that the energy the cars are receiving and using are emitting the lowest possible carbon.

Solar Canopies:

The production of energy is the most important factor in reducing emissions. Without producing some form of clean sustainable energy, emissions from the college fleet are not actually being reduced. They only shift emissions from the use of oil to the electric grid that would be used as a power source for the vehicles. A solar carport or canopy can provide the opportunity to utilize solar panels to produce the energy needed to power the newly purchased electric or plug in hybrid vehicles as well as multiple charging stations.

What is a solar canopy?

Referencing the picture below, a solar canopy is a multifunctional roof structure located above a paved area such as a parking lot. The most important component is that it generates energy using the solar panels located all over the protective cover area. However, this structure also provides shade for cars during the summer months and acts as a snow cover for cars during the winter months. As an alternative to rooftop solar, solar parking canopies are installed above parking lots negating the need for the roof of a building in order to install panels. The elevated nature of the canopy allows for a car or series of cars to be parked underneath the structure. The structure then generates power from solar energy, utilizing its 10 degree tilt to capitalize on capturing energy throughout the day. These canopies include solar panels and inverters to convert the direct current into usable alternating current. Solar canopies have become a popular trend in recent years as schools, communities, and cities look to take advantage of wasted paved spaces. Rutgers University boasts an array of solar canopies that produce electricity for the school. "The 32-acres of solar canopies generate eight megawatts (mW) of power, or approximately $1.2 million in electricity – equivalent to the annual energy consumption of nearly 1,000 households" (Miranda, 2011). This proves that colleges are taking initiatives to become more sustainable and that solar canopies are a viable source of energy to help achieve carbon neutrality.

https://www.livescience.com/41995-how-do-solar-panels-work.html

Figure 5: "Parking Lot Solar Canopy", (Cincinnati Zoo, 2011)

Our intention is to use a group of solar canopies similar to the one pictured above and the one described at Rutgers University in order to produce energy for the electric car chargers as part of our plan to reduce emissions. This type of system has been integrated with success at other institutions of higher learning such as IIT [Illinois Institute of Technology], where a solar canopy along with six level 2 chargers were implemented in order to charge electric vehicles on campus (Tian 1).

Figure 6: "Rutgers Solar Canopy", (Rutgers University, 2019)

Where to put the solar canopies?

The prime location for implementing solar canopies is the Bushkill parking lot at 901 Bushkill Drive. The 302 spot parking lot is roughly 75,000 square feet, providing plenty of room for the implementation of solar canopies (Lafayette College Technology Clinic 31). A 50kW solar canopy suggestion would require 3,526 square feet of space. This would cover less than 5% of the Bushkill parking lot and thus provide minimal inconvenience during the construction process. The college can also make the canopy larger if it also wants to use the electricity generated to power surrounding light or the Public Safety building. Additionally, with little to no high structures or trees impeding the sunlight, the lot provides an ideal location open to the sky for solar energy production. The open lot is not currently operating at maximum capacity meaning there is plenty of room to be set aside for electric charging areas. All of these factors along with the close proximity of public safety and campus facilities being on either side of the lot makes this area perfect for the implementation of the energy production and distribution parts of our plan.

Figure 7: "Bushkill Parking Lot", (Google Maps, 2019)

How much energy can be produced by a solar canopy?

The amount of energy produced by the canopy is tied to two major factors. The first of which we cannot control is the weather. A common misconception is that solar panels lose a majority of their production on a cloudy day. This is largely untrue as most solar panels only suffer a reduction in production of around 10% to at most 25%. (Paradise Solar Energy, 2019) But a reduction is a reduction so we must keep this in mind that the power production will vary from day to day. The second factor that will impact the amount of electricity produced by the system is the number of canopies that we install over the available parking space. With each additional canopy more electricity can be harvested and therefore passed on to charge the electric fleet of vehicles. Through our calculations outlined below we have discerned that in order to power one vehicle we need to implement roughly 28.8 solar panels. Therefore, to accommodate the charging of at least 25% of the fleet each day we would need ten times the 28.8 figure making the total panels needed 288. The beauty of the solar canopy is that the design is flexible and can be structured to meet differing panel demands.
[This figure assumes the cars would not need to be charged each day and instead only roughly 10 cars a day would need to receive a full charge]

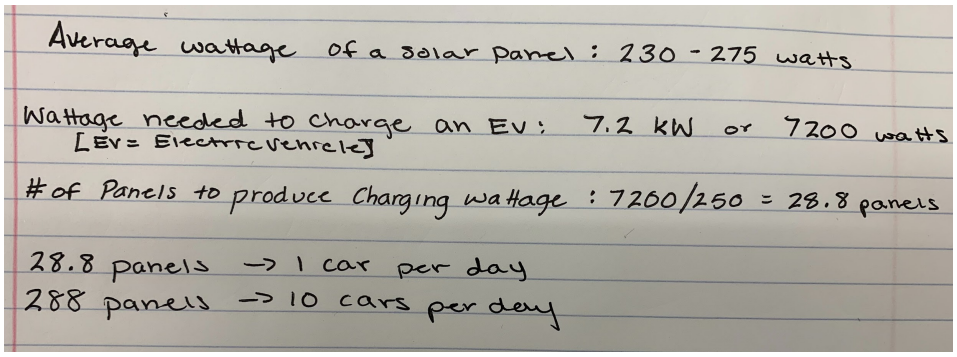

Figure 8: "Solar Panel Calculations", (Currie, 2019)

Our group assumed a Lafayette owned vehicle travel 20 miles a day for analysis purposes. For a vehicle to receive a 20-mile charge, it would require 6.3kWh of energy. The economic analysis provides more detail to determine the optimal canopy size and encouraged the recommendation of a 50kW solar canopy with a square footage of 3,526 (Solar Electricity Supply, Inc). Easton averages 4.5 to 5 kWh/m^2/day which is known as peak sun hours (Solar Power Rocks). Assuming 4.75 peak sun hours, a 50kW solar canopy should produce 237.5kWh of energy per day. This amount of energy should power every car and then be able to sell the excess energy back to the grid, providing Lafayette with added benefits. These monetary benefits are further expanded upon in the economic section.

Additional Technical Benefits of Solar Canopies

In addition to the obvious benefit of producing renewable alternative energy to power our fleet, the solar canopies offer a host of other benefits to the college fleet and the greater Lafayette community's vehicles. These include an increase in shade, weather protection, tan credits, and a maximization of available space here on campus. The implementation of these solar canopies will create a structure that any vehicle can park under whether is is electric or not. It has been proven that a cars air conditioning on a hot day can increase the total emissions from a vehicle over the course of driving. (EPA, 2019) By utilizing the shade produced by the structures the average temperature will likely decrease resulting in reduced emissions from cars on Lafayette's campus. Additionally, the angle and elevation of the structure will likely provide protection from most weather events such as snow and rain which could potentially damage vehicles and the underlying pavement at Bushkill parking lot. Finally, implementing the solar canopies eliminates the possibility of Lafayette College purchasing and developing another large area in order to build a solar array. Instead of having to waste space out at the Metzgar complex and designate space solely for the purpose of solar panels, the college can focus its efforts in an area closer to the school where the electricity can be more effectively utilized.

Charging Stations:

Lafayette's current situation:

Charging stations are one of the most crucial components of this project. They are essential if Lafayette College wants to make an impactful transition towards a more sustainable transportation system. Currently, the only college-owned electric vehicles on campus are comparable to golf carts and used conservatively. As stated in the political context section, there are currently six charging stations on campus, located at Markle Hall parking deck, Watson Hall parking lot, and 901 Bushkill Drive. Each station is a Level 2 power level, meaning they provide energy through a 240V AC plug. These charging stations can be connected to the electric grid or powered by other energy sources such as the solar carport presented in the previous paragraph.

What types of charging stations are available?

Three different types of charging stations are available for purchase. Level 1 charging stations are the cheapest of the three alternatives and are equivalent to an outlet on a wall. They also produce the lowest energy output, resulting in extremely long time periods to provide a full charge. Some Level 1 options include a 4mi/hour @1.4kW and a 6mi/hour @1.9kW meaning it would take over two days to fully charge a 300-mile Ford Explorer tank (US Department of Energy 2015). The low costs do not outway the disadvantages associated with these excessively long charge times, so it is not a viable option to power a potential electric Lafayette fleet. Level 2 stations are more expensive, but provide much quicker charge times that will allow vehicles to achieve a full charge in a few hours. These options range between 10mi/hr and 60mi/hour,

providing Lafayette with the ability to fully charge each vehicle in as little as five hours. This provides drivers of these vehicles with more flexibility and an increased convenience factor. The Level 3 stations were also considered and would be able to charge each vehicle in under an hour, but also require tens of thousands of dollars to purchase each station. This option was disregarded due to the massive price tags associated with them. Another advantage of the Level 2 charging station is that it is compatible with electric vehicles and plug-in hybrids. Level 3 stations are only compatible with specific vehicle models and would restrict Lafayette College when replacing the current fleet.

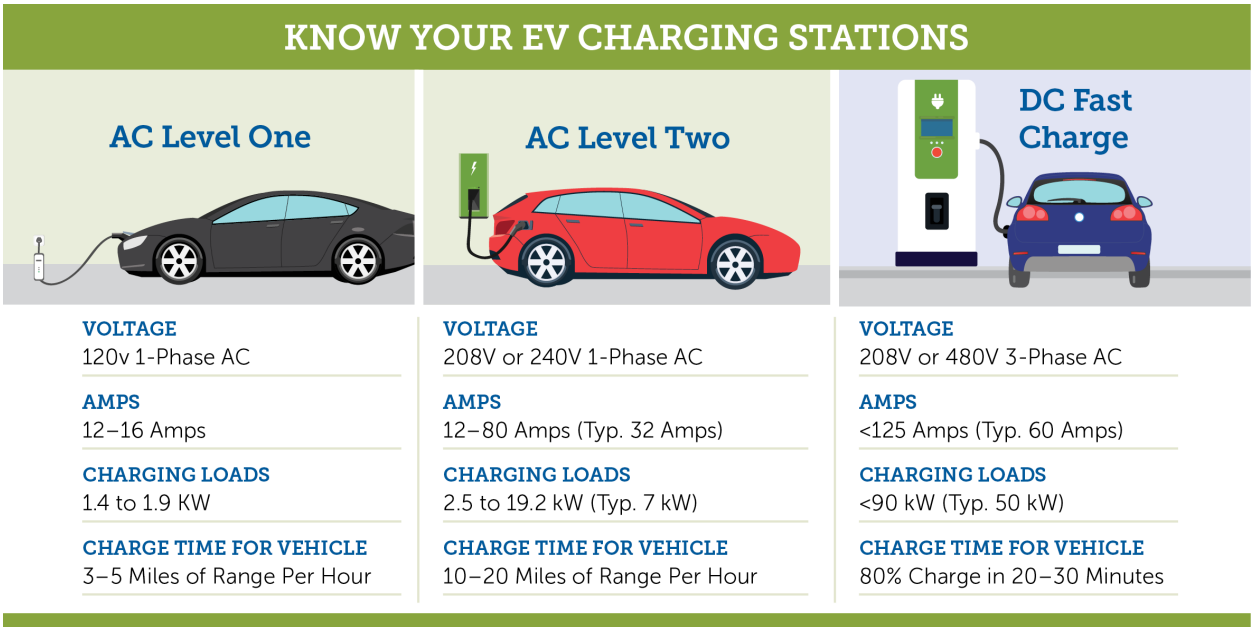

Figure 9: "EV Charging Stations Comparison", (Carolina Country, 2019)

One of the best Level 2 charging station brands is Chargepoint. First, it has already been installed on multiple college campuses including Boston University, which was awarded a federal grant to install two Chargepoint stations on its Medical Campus in 2011(BU.edu 1). It also has additional features that would be useful for the Office of Sustainability as well as other stakeholders willing to analyze its usage. Each station is linked to an online dashboard that provides valuable information to the viewer including the amount of chargers in use at any given time and any problems that arise. This makes it much easier to troubleshoot problems and fix any bugs or inefficiencies that may occur at the station (Agrawal 2). The stations are also linked to online accounts, making it very easy to manage expenses for charging college owned vehicles. The usage, costs, and payment method are very convenient, allowing Lafayette College to analyze the data and use it to make decisions in the future.

Figure 10: "Level 2 Charging Station", (Chargepoint, 2019)

Finally, we made the decision to recommend 4 Level 2 charging stations with two ports each. This would provide Lafayette with the ability to charge 8 vehicles simultaneously. There would then be enough stations to meet demands for 19 years with the assumption that Lafayette replaces two vehicles every year and that each vehicle requires 6.3kWh of energy per day. Lafayette then has the option to add more stations in the future if it is deemed necessary.

How would Lafayette power the charging stations:

For our purposes we are going to focus on using solar canopies as a sustainable energy source to power the charging stations. The ultimate goal is to reduce transportation emissions from Lafayette owned vehicles, so transitioning to electric vehicles would not be effective unless there is a sustainable form of power. Installing Level 2 charging stations connected to the current electric grid would just shift energy consumption without actually reducing emissions. The most sustainable method available is to use the energy generated from the solar canopy mentioned earlier to supply electricity to the stations. This smart grid system results in an effective alternative to traditional vehicles (Singh and Sudha Letha 2047). However, the solar energy generated by the canopy cannot be directly used by the Level 2 charging stations. There must be solar inverters incorporated into the system to help convert the energy created by the solar canopies, known as direct current (DC), into alternating current (AC) that can be used by the stations (energysage 1).

There are multiple inverter options including string inverters, power optimizers and microinverters which each provide varying levels of energy efficiency. Each option performs the same action of converting energy created by solar panels into usable energy, but the string inverter and power optimizer can only produce as much useful energy as the least productive panel (energysage 1). Microinverters are different and have converters attached to each panel as opposed to a singular one that converts all of the generated solar energy. This option is more expensive but will provide a much greater benefit to the entire system. The alternating current produced by the inverter is then stored and available to power the charging stations whenever they are in operation. The AC is then usable by electric vehicles and hybrids, significantly decreasing emissions from the Lafayette fleet (Electromobility 1).

How does the installation process work?

Installation of Level 2 charging stations is very similar, but does carry a significant price tag. The best option is to schedule a time with either the manufacturer or another electrician that specializes in charging station installation and have them incorporate the necessary 240V circuit to the newly designed space (New York State Energy Research and Development Authority 6). It is also important to figure out the optimal location for each charging station. Ideally they should be as close to the solar canopy as possible, however it cannot be too far in the corner of the Bushkill parking lot or else faculty might be less inclined to use them. They also shouldn't take up parking spaces too close to the Public Safety building or else it inconveniences those that would normally park in those spaces. There needs to be a balance between being out of the way and not being too far away that it inconveniences people to get to the charging stations (New York State Energy Research and Development Authority 5).

Cars / Vehicles:

The final component of this transition to lower transportation emissions involves actually replacing the current fleet of Lafayette vehicles. There are currently 109 vehicles owned by Lafayette, 37 of which have expiring useful lives in the next year. A significant portion of these expiring vehicles are vans and trucks used to transport people and equipment around campus. These vehicles are much less fuel-efficient than current standards and options on the market. For example, Lafayette owns four Chevy Venture Minivans purchased in 2004 and nine GMC Savana Vans purchased between 2006 and 2015 (Lafayette College Vehicle List). These two options have estimated miles-per-gallon of 20 and 15 respectively (fueleconomy 1). These vehicles are also over 10 years old and become much less efficient as they increase in age.

These vehicles need to be replaced by electric and hybrid plug-in cars available on the market today to reduce emissions from Lafayette owned vehicles. Allocating resources towards hybrid vans or SUVs is a topic that the Board and influential stakeholders in Lafayette will discuss when sustainable energy sources are already implemented, but there are multiple options to consider. These include the Chrysler Pacifica Limited Hybrid (shown below), Ford Explorer Limited Hybrid, Volvo XC60 Plug-In Hybrid, and the Toyota Highlander Hybrid. These options range between 30-80 combined mpg and $45,000-$65,000 per vehicle. The most crucial part of this turnover schedule is deciding when to purchase more sustainable vehicles. There are already going to be significant initial costs associated with constructing the solar canopy and implementing multiple Level 2 charging stations. This might make it difficult to allocate even more resources towards hybrid or electric vehicles. As stated previously, 37 of the 109 licensed vehicles are at the end of their useful life in 2020, so these vehicles need to be the first ones replaced. 25 of the vehicles then hit the end of their useful life in either 2021 or 2022. There are

then 47 vehicles that have a useful life until after 2023, which gives Lafayette some flexibility with timing.

Figure 11: "2019 Chrysler Pacifica Limited Hybrid", (Chrysler, 2019)

The decisions made are crucial for the efficacy of this project, but the spacing of expiring vehicles does allow for a realistic replacement schedule. It is also important to understand that there have been significant strides in recent years regarding fuel efficiency improvements and higher standards. In 4-5 years, ranges and emissions levels for different hybrid options should improve and provide even more benefits to Lafayette as well as more electric car options for consumers to purchase. The decision of what make and model will not be relevant until the proper energy source is implemented, however it is still important to understand where the market is headed and potential options the college has going into the future.

Economic Context:

The economic analysis for this project needs to be heavily considered if Lafayette were to actually implement something like this. The main focus of this economic analysis is going to be the solar carport. As talked about in prior sections, while electric vehicles do reduce emissions, they mainly just shift the emissions from the car itself to the grid that produces the electricity. This is why we find it necessary to consider the cost of the solar canopy first before considering vehicle cost. In this section, we will cover both financial and non financial benefits to the solar carport as well as the total cost of the solar carport.

To start, as stated in the social contexts, a solar carport would align directly with Lafayette's plan to be net zero by 2035. The solar carport would be a way to show the Lafayette community that the administration is dedicated to achieving these goals. While Lafayette has done a lot to move towards carbon neutrality, many of the steps the school has taken are not incredibly obvious. The solar carport is something that screams sustainability and would be a

beacon to the school to showcase Lafayette's commitment to the Climate Action Plan 2.0. The Environmental Protection Agency has a presentation called *Solar Carports: Turning University Parking Facilities into Renewable Electricity Plants,* in which multiple benefits to building a solar carport are presented . These benefits include:

- Reduce the college's carbon footprint
    - Aligns directly with the schools goals
- Reduce electricity expenditures and hedge against future cost increases
    - We would be spending less on electricity which helps reduce the risk of the increase in the cost of electricity
- Increase efficiency of under-utilized space
    - Bushkill parking lot has the potential to be much more than just a parking lot
- Improve parking experience for students, staff, and visitors
    - Protects those in the parking lot from snow, rain, and harsh sunlight
- Encourage environmentally-friendly forms of transportation
    - More people willing to bring their electric vehicles to school if they know charging is available

While the project itself will cost money, it will also generate revenue by lowering electricity cost. On top of this there are multiple intrinsic values that are important for both the reputation of Lafayette as a member of the American College and University Presidents' Climate Commitment (ACUPCC). There are also benefits that the solar carport has for those using the parking facilities. The solar carport provides protection from the elements from the sun, rain, and snow for both the car and it's owner (EPA). In the summer months, the shade will help with the fuel economy of any vehicle in the parking lot as "AC use can reduce a conventional vehicle's fuel economy by more than 25% particularly on short trips" (Fuel Economy in Hot Weather). All of these benefits are the reason that the school would accept the loss of money to conduct the solar carport project.

In order to get a better perspective of the cost of this project, it is important to look for similar projects to find out how they were priced. Jessica Polivchuk wrote an academic document called *Exploring the Feasibility and Costs and Benefits of Solar Carports for the Calgary Parking Authority* in which Polivchuk does extensive research on the cost and benefits of a solar carport project for the Calgary Parking Authority in Canada. Polivchuk lays out the projected costs for a 160KW Solar Carport in this table below.

Estimated Project Costs for a 160 KW Solar Carport Project in Lot 59 (2018$)

Expense Item	Budgeted Cost
Solar PV modules	196,000
Inverters	21,000
Power optimizers	26,000
System materials (cables, switch gear, AC and DC disconnects, etc.)	90,000
Design and permits	20,000
Installation labour	50,000
Aluminum carports	230,000
Geotechnical report	3,900
Foundation piles (material and installation)	9,984
Total (excluding GST)	666,884

Figure 12: Estimated Project Costs for a 160 KW Solar Carport (Polivchuk 25)

As we can see from this table, there are many costs that go into a solar carport projects. The main ones are the Solar PV modules and the physical carport bodies. Energysage Solar Marketplace has reported that it cost approximately $3.99 to build a solar carport. Since we do not have the time in this project to conduct an entirely accurate estimate, we can check to see if this number is accurate enough for us to use. If we use the Energysage estimate, we find that Polivchuk's project would have costed 160,000*3.99= $638,400 which is not far off from the $666,884 that the project cost. The Energysage estimate is slightly below the actual cost of Polivchuk's projections, however the cost will certainly vary based on a multitude of factors. This does show that the Energysage estimate is at least somewhat accurate and can be used in further calculations.

In order to calculate the financial benefit of the solar panels, we need to figure out how much energy the solar panels will produce. According the Solar Power Rocks, Easton PA averages 4.5 to 5 kWh/m^2/day. This is known as peak sun hours and is defined as "a measurement of the sun's intensity over an average day, expressed as the equivalent of the sun shining at peak intensity for a certain number of hours" (Zientara). This means we can assume that our solar panels would get us about 4.75 peak sun hours. We can use the equation

50kW x (4.75 hours x 365 days) = 86,687.5 kWh per year

This means that our 50kW solar canopy will produce on average 86,687.5 kWh per year. The average cost for commercial energy in Easton PA is 5.61 cents per kWh(electricity local). This equates to annual savings of $4,863.16 if all of the electricity was sold back to the grid.

The current plan for this project is to add two electric vehicles to the fleet every year. In order to calculate how much energy each vehicle will require, we first need to figure out how many miles they drive. According to AAA Newsroom, Americans drive 29.2 miles per day. Since the Lafayette College fleet only drives on campus and does not touch the highways, it is safe to assume that these vehicles are being driven less than the american average. We will estimate that the vehicles average 20 miles per day. It takes 3.5 hours to charge an 80 mile battery (Chargepoint). The equation 3.5 hours / 80 miles = x hours / 20 miles can be used to find that it

takes .875 hours to charge an electric vehicle 20 miles. .875 hours x 7,200 watts = 6,300 watts to charge a car 20 miles. This is necessary in calculating the total savings on electricity per year. The table below shows the financial economic analysis for this project. Column A shows the amount of cars and each row is a new year. Column B is the savings on electricity which is calculated by using this equation:

Savings on electricity = (Savings per year - (((Amount of Cars * 6.3KwH) *365) * Cost per Kw)
1st Year: $4605.16 = ($4863.16 - (((2 *6.3)*365)*.0561)

The savings on electricity values are then converted to the present value using the current inflation rate and the amount of years away from the present. These values are totaled to get a total of $38,813.98 dollars on electricity savings assuming the cost of electricity is constant.

	A	B	C	D	E	F
1	Amount of Cars	Savings on electricity	Present Value			
2	2	$ 4,605.16	$4,525.96	Cost per kw		
3	4	$ 4,347.16	$4,198.91	0.0561		
4	6	$ 4,089.16	$3,881.78	Inflation Rate		
5	8	$ 3,831.15	$3,574.31	1.7		
6	10	$ 3,573.15	$3,276.27	Cost to build Solar Canopy per watt		
7	12	$ 3,315.15	$2,987.42	$3.99		
8	14	$ 3,057.14	$2,707.54	Watts		
9	16	$ 2,799.14	$2,436.40	50,000		
10	18	$ 2,541.13	$2,173.79	Cost to build Solar Canopy		
11	20	$ 2,283.13	$1,919.49	$199,500.00		
12	22	$ 2,025.13	$1,673.30	ITC Insentive		
13	24	$ 1,767.12	$1,435.01	0.3		
14	26	$ 1,509.12	$1,204.41	$139,650.00		
15	28	$ 1,251.11	$981.33	4 level 2 Charging Stations		
16	30	$ 993.11	$765.56	$20,000		
17	32	$ 735.11	$556.93	Cost		
18	34	$ 477.10	$355.24	$159,650.00		
19	36	$ 219.10	$160.33	Savings - Cost		
20	Total Savings	$ 43,418.37	$38,813.98	($120,836.02)		

Figure 13: 50Kw Bushkill Parking lot Savings and Cost

In order to calculate the cost of the solar carport, we used the Energysage Solar Marketplace estimate of $3.99 dollars per watt which equates to $199,500.00. There is a federal tax credit that equates to 30% of the final cost of the solar system (Pennsylvania Solar Incentives) which brings the price down to $139,650. If we subtract the savings from the cost it turns out that the entire cost of the project will be approximately $120,836.02.

Overall, a solar carport will run the school approximately $120,836. This cost however is offset by multiple different benefits. These benefits include the reduction of emissions, enhanced parking experience, increased efficiency of underutilized space, and reduced electricity expenditures. This is a project that would certainly also enhance Lafayette College's standing as a school committed to sustainable practices. If the college is to take the Climate Action Plan 2.0 seriously, a method of reducing emissions from transportation is necessary. A solar carport is the most economical for the long term implementation of electric vehicles.

Conclusion:

During ten weeks in the Fall semester of 2019, our group took a detailed look into how we could reduce emissions from the transportation sector here at Lafayette College. This project came on the heels of the College passing their Climate Action Plan 2.0 earlier on in 2019. The Climate Action Plan acted as an anchor for the project. It outlined the issue of emissions from the transportation sector needing to be reduced. However it gave very little methodology on how to approach that situation. The Lafayette College vehicle fleet was aging and in need of some serious alterations if it was to be seen as a sustainable piece of Lafayette's transportation sector.

We started with a seemingly simple question of, "How can we reduce the emissions from the transportation sector here at Lafayette?". We quickly discovered that purchasing a whole fleet of electric cars was out of the question as it did not truly solve our problem. We wanted to reduce the emissions produced here at Lafayette, not just shift them to the power plant down the road. We found that our solution was not a singular solution, but instead it was three separate components working together to create one cohesive system. Our solution was to combine sustainable energy production, electric car chargers, and electric and hybrid electric vehicles in order to reduce emissions from the vehicle fleet here at Lafayette. We found solar canopies in the form of solar carports allow the perfect medium for clean energy production to power our vehicles. By utilizing the wide open Bushkill Parking lot we would be able to implement an array of solar canopies, generating a significant amount of electricity to power the new cars without designating a certain plot of land solely for the purpose of solar panels. This energy source would also act as a potential revenue source for the college by selling any unused electricity back to the electric grid. Then by pairing the solar canopies with Level 2 electric car chargers we would be able to harness the energy created by the panels and channel it into the vehicles to power them without creating the large amount of GHG emissions associated with traditional vehicles powered by fossil fuels.

When we dove deeper into the contexts surrounding the project, we found further support and guidance into the direction we wanted our project to take. The social environment surrounding this project proved that this project would not have been possible 10-15 years ago because the technological aspects were not as common and accepted by society. Electric charging, electric vehicles, and solar panels have all experienced a surge into mainstream society within the past few years making them prime targets for Lafayette College to utilize. This is a

result of people beginning to recognize the issue of climate change. Climate change has invigorated politics and people alike to start addressing issues such as emissions by creating policies such as the Energy Policy Act as well as altering personal habits. As an elite liberal arts school Lafayette needs to bolster its reputation further and stand apart from its peers if it wants to reach the level of sustainability outlined within the Climate Action Plan 2.0.

Figure 14: "Lafayette's Mission to Sustainability", (Office of Sustainability, 2019)

In the long run this project should serve as an example for others to study in order to replicate our efforts in emissions reductions. Climate change is seen as a daunting task that no one individual or organization can truly change, but this is inaccurate. Each individual effort adds up and that is how lasting differences are made in the long run. A small reduction in emissions at a liberal arts school likely will fall short of solving climate change, however the ability of other schools and companies to look at our project and replicate it for their own fleets has the chance to actually put a dent into this massive problem of climate change.

As for the immediate future of this project here at Lafayette, there are several things that need to happen. First and foremost this report needs to be seen and scrutinized. The office of sustainability should review our research and findings. Then the office can determine if this is the route they imagined the project taking. If not, then they can return to the drawing board with a new capstone group next year. If Lafayette College actually wants to take steps towards carbon neutrality in the transportation sector then they will need to make some impactful decisions in the next few years. Over 60 licensed vehicles reach the end of their useful lives by the end of 2023, meaning there must be a plan in place once these cars do need to be replaced. Secondly, the people taking over the project should look to get more input and consultations on the proposed idea. These do not have to be expensive consulting firms charging outrageous costs but instead could very well be students, faculty, and employees of the school to get their input into whether or not they see this project as feasible. Finally, the report should be continually updated and expanded upon with new information. We have already looked upon schools from California like UC RIverside and even Rutgers in New Jersey on their attempts of implementing solar canopies. The more we can learn about how these projects function in the real world, the better chance this project has of working in its implementation down the line.

As students and faculty expand on different facets of this project, there needs to be constant communication with the Public Safety office and Department of Facilities as well.

Individuals in these offices not only have numerous resources available to them to provide deeper insight into different analyses, but are also going to be the individuals impacted most directly. They will be the ones accommodating any installations of solar canopies and charging stations, driving the vehicles, and providing valuable insight into problems that may arise in the future. In any project it is crucial to create a collaborative environment that holistically tackles a common goal. This situation is no different and hopefully other groups will be able to expand on the foundation set by our group to produce real change on Lafayette's campus.

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