Auditing Solar Panels on Building Rooftops at Lafayette College: A Feasibility Study

Sam Bernhardt
Aaron Gabay
Brian Luther
Nicolette Lupo

LAFAYETTE COLLEGE

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Dr. Benjamin Cohen
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INTRODUCTION

Background

Using solar technology, energy from the sun can be harvested and used as a renewable power source. Solar energy provides renewable energy without emitting any fossil fuels or having negative effects on the environment. In the past few years, solar energy has emerged and continues to improve as an effective renewable energy source (J. Nicodemus, personal communication, 2017). The functional capabilities of solar energy are proving to be even more beneficial as climate change continues to remain an important global issue. Currently, carbon dioxide levels are at their highest level and sixteen of the seventeen warmest years on record have occurred since 2001 (NASA, 2017). Statistics like these prove the severity of climate change and increase the importance of implementing renewable energy sources.

College and universities have emerged as capable suitors to implement renewable energy, specifically solar energy, on their campuses. As colleges continue to strive to represent model communities, sustainability efforts are a top priority. There are a plethora of examples of colleges across the nation adding renewable energy systems to their campuses. These colleges are not just helping the environment; they are showing their commitment to be sustainable in a visible way. Furthermore, prospective students value institutions that make visible strides towards sustainability and an eco-friendly environment. The following report will look deeper into Lafayette College's ability to implement solar energy systems on its own campus.

Problem Definition

Lafayette College has made strides towards sustainability and an environmentally friendly campus, however these efforts lack visibility. In the last year, the college hired a

Director of Sustainability which never existed at Lafayette before. On top of this, ground has broke on the new Rockwell Integrated Sciences Center. When completed, this building will be one of the most energy efficient science centers in the nation with a LEED gold certification. These major steps demonstrate Lafayette's commitment to sustainability, but are not visible to people walking around campus. Even when the new science center is complete, no one will know it is LEED Gold simply by seeing it from Anderson Courtyard. Similarly, no one visiting College Hill would know that Lafayette has a new Director of Sustainability without doing any research.

College campuses are seen as model communities, and university sustainability is moving further into the mainstream with each passing year. Because of this, we believe it is important for Lafayette to increase the visibility of its sustainability efforts on campus. One way to do so would be to implement solar energy systems on the rooftops of buildings on campus. Our team performed an energy audit of Lafayette's campus. The question we hoped to answer is as follows:

Can Lafayette implement feasible and effective solar energy systems on the rooftops of buildings and where?

In order to answer this question in a clear and comprehensible way, we considered four different contexts that are relevant to the problem: social, political, technical, and economic. The majority of this report details our analysis of each of those respective contexts.

Challenges

There are a couple of challenges in adding solar panels to roofs that came up in our analysis. Through discussion with Lafayette personnel, we learned that not every building is capable of having solar panels installed on its roof. Some roofs are not able to support the weight while others are too steep. The challenge of load capacity became an important variable in our technical analysis.

The biggest challenge in terms of convincing Lafayette that renewable energy systems are worth implementing on campus is the cost. We go into detail about costs and estimates in our Economic Analysis, but a recurring theme in discussions with people on campus was that our largest hurdle would be the finances. We understand that solar energy is currently more expensive than fossil fuels in Pennsylvania, but we hope to prove that there is other value besides just dollars that comes from implementing renewable energy systems on campus. Furthermore, just because something is cheaper does not mean it is right. Child labor is a cheap alternative to paying adults a salary, but it is wrong. In this case, fossil fuels are a cheap alternative to adding solar panels to roofs, but knowingly polluting the environment when there are cleaner alternatives is wrong. The school has shown its willingness to pay for sustainability. The Rockwell Integrated Sciences Center is a 75 million dollar project. A percentage of that costs comes from the fact that it is going to be a LEED gold building. Lafayette certainly could have designed a new science center that is cheaper, but it would not have been as sustainable or environmentally friendly as Rockwell will be. The college's benefits of having a LEED gold on campus rationalized paying the extra money to do so. We believe the same logic should apply when choosing whether or not to implement renewable solar energy systems on campus, and hope that this report can help the school realize that.

Goals

There are several established goals of the following research project. Our first goal is to answer the question we outlined above: can Lafayette implement feasible and effective solar energy systems on the rooftops of buildings and where? The project addresses feasibility from four different perspectives: social, political, technical and economic. The paper will explain where the optimal locations for solar energy are on campus, the type of panel recommended, and the value added from implementing solar panels. The paper will aim to prove to Lafayette College why the school should or should not implement solar energy on campus through analysis of the contextual perspectives noted above.

We realize that the analysis necessary to make fully informed decisions about whether or not to add solar panels to roofs on campus, which roofs are ideal, and how many panels is beyond the scope of a fifteen week project. Because of that, another one of our goals is to lay out next steps. We hope that in the future any group of students along with the Lafayette administration can use our report as a natural starting point for assessing the feasibility of adding renewable solar energy systems on campus.

Section Overview

Social Context

The first section of the research is social context. First, social context will help to explain why the question of implementing solar energy at Lafayette College is being asked in the first place. The social context section then looks into how implementing solar energy fits into the current society. Social context is analyzed at the global scale, among higher education institutions in the United States, and on Lafayette's campus. The research goes into how solar energy would be accepted on campus and the impact it will have beyond just the technical aspect of being a renewable energy source.

Political/Policy Context

The political and policy context section of our report focuses on the impacts the environmental movement has on global governments, specifically the European Union's policies versus the United States' environmental policies. This section delves deeper into how the global movement affects college campuses across the United States. By analyzing multiple colleges and universities, we are able to see how colleges act as role models for ideal living communities. The end of this section discusses funding considerations necessary to implementing solar panels on campus, as well as relevant environmental policies undertaken by Lafayette College.

Technical Analysis

The technical context section analyzes the technical aspects that are involved in implementing solar technology on campus. The section analyzes different types of solar power, looking into the photovoltaic and solar thermal. Furthermore, we will derive equations for returns on energy to be able to establish how much energy solar panels can actually supply. Lastly, a technical analysis of potential locations for solar panels will be performed in order to find the optimal location.

Economic Analysis

The last section is economic context. In this section, the economic factors of implementing solar panels at Lafayette College are analyzed. The section will look into the cost of installing solar panels along with how much its costs will compare to the current energy budget. The economic section will also work to assign value added to qualitative value in order to show the total added benefit from installing solar panels at Lafayette College.

SOCIAL CONTEXT

Introduction

Although solar energy systems would be a highly technical project for Lafayette to invest in, there are a multitude of non-technical factors that must be discussed. The reasons for wanting to implement these systems on campus broach many different contexts and these must all be considered when determining the feasibility of a solar audit. Climate change is the most overarching context that is a driving force for a solar initiative on campuses across the nation. Next is how Lafayette fits into the American college community and how it can remain competitive with other institutions in a variety of ways. Finally, our most narrow context is what kind of message visible solar panels would send to campus visitors and the community as a whole. Each of these plays a role in the value that solar energy systems have to Lafayette and each must be considered when making a decision.

Climate Change (Global)

In recent years, climate change has been in the news a noticeable amount. Its effects have been seen and felt all over the globe and many nations are doing what they can to help the planet. Because of this, there has been a strong environmental movement for us to each do our part. The Paris Agreements recently made the environmental goals of every country more clear and although President Trump declared his intentions for the United States to pull out of the agreement, many American businesses and institutions have made it abundantly clear that they are still willing to make conscious efforts to reduce carbon emissions and invest in energy efficient technologies (Victor, 2017). Switching from fossil fuels to renewable sources of energy such as solar would be a step in this direction.

Countries around the world realize that climate change is an international issue that is affecting everyone. It is a problem that does not see country borders or beliefs; therefore, it should be solved through international collaboration. Each country sets its own goals and initiatives through the Paris Agreement; the only criterion is that they should improve over their own current efforts (Paris Agreement, 2015). We can learn from what the European Union is doing and try to follow their example in the United States. These European efforts and how they compare to what the Environmental Protection Agency (EPA) is doing will be discussed in more depth in the Political Context.

Media has also played a role in spreading awareness for climate change. With the rise in climate change related events such as hurricanes and flooding, the world has seen the environment become a hot topic to discuss. A study in Japan looked at how prevalent topics were in the news and found that the environment has skyrocketed to being one of the most discussed issues (Sampei and Aoyagi-Usui, 2008). It passed both peace and nuclear weapons, among other topics, in 2006. This exemplifies the role the environment has started to play in the international narrative and serves as an example of how climate change has taken the spotlight in the news.

All of these things add to an international pressure to become a more sustainable college. Seeing all these international efforts should serve to reinforce the idea that climate change is a real issue, one that we should all be doing our best to mitigate and adapt to. Saving the environment is an issue that countries all over the world are devoting themselves to as can be seen in the Paris Agreement and if Lafayette wants to continue to be a be a competitive college, it should strive to continue to embody these ideals and improve upon them. With the prevalence of climate change related news, creating visible sustainable efforts on campus can be the catalyst that sparks an interest in preserving the environment for students.

Lafayette College values sustainability and realizes its role and responsibility as a part of the global community to be environmentally aware. As per the Campus Master Plan, Lafayette aims to be a sustainable campus and strives to have the smallest impact on the environment possible. In January of 2008, Lafayette also signed the American College and University Presidents Climate Commitment (ACUPCC) which doubled down on this value. Since then, Lafayette has made an effort to reach its sustainability goals with its construction of the new Rockwell Integrated Sciences Center. While these efforts pale in comparison to the global scale, they are steps in the right direction for a college of Lafayette's size.

Climate change is a global force that is shaping the playing field in more ways than one. People all over the world are feeling its effects and are stepping up to do something about it. In order for Lafayette to hold true to its ideals and continue being a school with an international perspective, investing in sustainable energy is the correct move for the future.

Higher Education Institutions (Country)

Colleges in the US are plentiful and prospective students are looking for schools that stand out from the crowd. Sustainability and environmental awareness are issues that the younger generation values and are looking for in a college. While Lafayette does prioritize these values, as can be seen in our Master Plan (2009), our efforts are not easily noticeable and this is where visible solar energy systems and our project come into play.

Many other colleges have implemented visible sustainability efforts with varying degrees of success. The most successful colleges do not only have green programs on campus; they embrace the movement as a whole and integrate their ideas into the culture of the campus. For instance, Arizona State University implemented solar parasols to an area of their campus that was previously unusable due to high exposure to sun and high temperatures in summer. Solar energy systems brought a utility to this previously unused plaza and now their extended solar network brings in enough energy to power almost 4000 average US homes (Goldfarb, 2016). Although solar energy is much more efficient in Arizona, the idea can still be applicable here at Lafayette.

Efforts, like this one at ASU, have approached the topic of sustainability in a variety of unique ways and these will be discussed in later sections. The unifying theme of these projects is that they were campus wide initiatives that incorporated the community and built off of existing projects. They all also increased the amount of recognition on campus since it was much easier for students to notice the efforts going on. In Lafayette's case, Buck Hall was designed to incorporate solar panels in the future and is in a very visible place (J. Nicodemus, personal communication, 2017). This lends itself as a very clear option to make our sustainability efforts visible that will be talked about in the Technical Context.

Sustainability has become an important facet for colleges in the United States. This can be best seen in the creation of the Association of Advancement of Sustainability in Higher Education (AASHE). First launched in 2006, AASHE serves to help higher education institutions pave the way with sustainability efforts in the country. With hundreds of colleges already members, AASHE has grown very quickly and demonstrates the level of value that colleges in the United States are putting on their relationship with the environment. One of AASHE's strategic goals for 2017 is to "catalyze sustainability leadership in higher education through increased visibility and recognition." This speaks to the point that having visible progress on campus can inspire students to get involved. Having visible efforts also has the potential to attract prospective students to Lafayette.

In conclusion, colleges in the United States are where the leaders of tomorrow are being made. This means that colleges are the perfect environment to serve as model communities for the country. Colleges have the means and resources to stand out as examples for their surrounding communities. Students are looking for colleges that are doing this and want to get involved once they are on campus. Lafayette should strive to provide its students with opportunities where they can really make a difference and to remain competitive with colleges that are doing so.

Lafayette College (Easton)

Lafayette has made it a personal goal to increase its sustainability efforts and environmental friendliness. Our most recent Master Plan, Lafayette's far reaching plan of action for the future and the direction that it wants to head in, revolves around improving our campus in a few different ways, all working towards making our campus more sustainable. The biggest issue that Lafayette has run into has been creating visible ways to demonstrate the progress that we have made (M. Hyde, personal communication, 2017). Faculty and students stand by these ideals, but struggle to come up with apparent examples. While the new science center is a step in the right direction, Lafayette should not settle with only this project.

Part of the problem is that a lot of what Lafayette has done is not obvious to visitors on campus. For example, refillable water bottle stations and double insulated windows are not anything that would make someone stop and think about the environment, but they are both attempts at creating a better campus. Lafayette has a multitude of policies and systems in place to help its sustainability but they all suffer from a lack of clear visibility or publicity of any kind (M. Wilford-Hunt, personal communication, 2017). This is where incorporating visible solar energy systems would have the largest impact and create the most social benefits.

We want our efforts to be easily seen by prospective students who are looking at Lafayette as a potential home for the next four years. While students can read all about all of our current efforts and the eco-friendly design of our buildings, it is much more impactful for them to be able to point at something on campus that falls in line with their own values. After speaking with Dean of Admissions Matthew Hyde, he confirmed this belief. He stated that the number of students applying with an interest in environmental studies/sciences has only been increasing in recent years and said it is not a far leap to assume these students are interested in sustainability efforts. Grossman House is a current building on campus that is supposed to be more progressive, and yet there is nothing apparent about its appearance and it is not even on the tour route. Matt Hyde commented that the admissions office would love to have another talking point and a solar installation on campus could provide that.

Throughout the course of our project, it has become abundantly clear that, while it has gotten a lot cheaper in recent years, solar energy does not have immediate economic payoffs (Richardson, 2017). Solar energy has dropped to $1.65 million per megawatt in 2016. This is the cheapest it has been in over a decade. Using renewable energy would not reduce the college's energy costs for quite a few years. This will be examined more in depth in our Economic Analysis. However, the potential social benefits that the Lafayette community values outweighs any initial monetary investment. These benefits could come in the form of prospective students, community values, and an overall responsibility to our planet.

Lafayette has already demonstrated that it is willing to spend a little more money to make sure that its sustainability efforts and intentions are clear. The new Rockwell Integrated Science Center is LEED Gold certified which means that Lafayette put in more resources to make sure that it had a higher rating. The college could have just as easily settled for a lower LEED certification or passed on it completely as was told to us by Professor Cohen. This would have been the cheaper alternative and it is highly unlikely that incoming students would take the LEED certification of a building into consideration when looking at college. The fact that the college strived for a higher LEED certification goes to show that it is willing to spend more resources on something that it values. Lafayette has a progressive mindset and we think that implementing visible solar energy systems would be the next logical step for the school.

Another Lafayette specific issue that arose was the social acceptance of solar panels on certain buildings. It was brought to our attention by Professor Nicodemus that adding solar panels to buildings with historic value such as Pardee Hall could have repercussions with alumni who think that they would be ruining the aesthetic of the building. On the flip side, it could be a sign of progress since putting solar panels on an iconic building would show just how serious Lafayette is to its goals. Based on our analysis, Pardee does not seem like an ideal spot for solar panels, while we are considering more modern buildings on campus.

Conclusion

The social context for the feasibility of solar panels on Lafayette's campus span a wide set of criteria and topics. Visibility has been a central factor to the campus and something that it has struggled with in the past. While there are multiple sustainability policies in place, they lack recognition. Without visibility, Lafayette will suffer in the highly competitive college market since eco-friendly schools are becoming increasingly popular. Colleges across the country are increasing their efforts to be sustainable for many different reasons, with student interest being one of these. Another is the heavy international focus that is being put on the environment. With countries all around the world devoting themselves to being sustainable, it is hard not to see the importance.

POLITICAL/POLICY CONTEXT

Introduction

The political and policy analysis of our report focuses on the impacts the environmental movement has on global governments and what policies the United States claims to be implementing to aid in reducing the effects of global warming. After looking at the environmental movement on a global scale, our report delves deeper into the environmental movement of the United States by looking at college campuses across the country that act as role models for ideal living communities. The end of this section discusses the decision-makers in charge of implementing these policies and relevant policies undertaken by Lafayette College.

The purpose of this report is to provide insight into the current state of the environmental movement, how the global movement is affecting college campuses, and how Lafayette College is specifically playing a part in making a difference. As discussed in the Introduction and Social

Context, we believe that providing visible signs of renewable energy will show prospective students Lafayette's commitment to exhibiting sustainable practices. It was important to look at the environmental awareness movement from a global and a local perspective because it shows how college campuses respond to global issues.

Globally and nationally, there are many stakeholders involved in implementing beneficial environmental policies. Identifying key stakeholders that are specific to Lafayette is important in order to gain support to implement solar panels on the rooftops of buildings on campus.

Problem Definition

Globally, world leaders are attempting to implement policies to reduce effects of global warming. In the United States, it is evident that environmental policies are not a top priority within the government. As shown in Figure 1, according to survey results taken in early January of 2017, the environment is not even ranked in the top 5 for the American public's policy priorities. Since President Trump was elected, the public's national policy priority rankings changed only slightly. Roughly three-quarters say that defending the country from terrorism (76%) and strengthening the economy (73%) should be top priorities for the government,

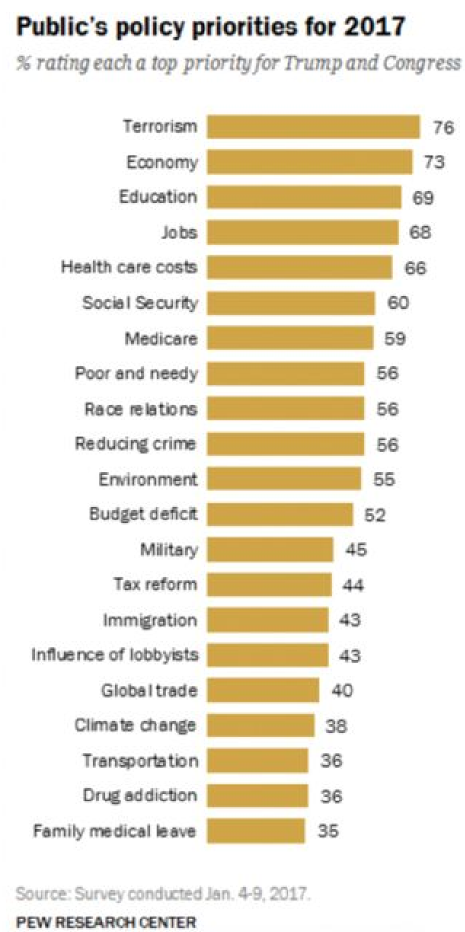

Figure 1: Pew Research Center's January 2017 survey for the American public's national policy priorities for 2017.

while at least two-thirds prioritize improving the educational system (69%), improving the job situation (68%) and reducing healthcare costs (66%). According to Pew Research Center, "a majority of Americans (55%) now cite protecting the environment as a top priority, up from 47% a year ago" (Pew Research Center, 2017). The United States Environmental Protection Agency's mission statement explains that their purpose is to "protect human health and the environment." After identifying environmental problems, the EPA tries to solve these problems by developing and writing regulations to Congress as they strive to set national standards that states and tribes should enforce through their own regulations. For those who do not meet these regulations, the EPA is there to help (US EPA, 2016). However, compared to other countries, the United States is not doing enough. As the third most populous country in the world and a world superpower, the United States should be one of the dominant leaders of the environmental movement.

European Environmental Initiatives vs United States Environmental Initiatives

Source: http://ec.europa.eu/environment/action-programme/images/7APnewlogo.jpg

In recent years members of the European Union, as a whole, have become progressive with the need to take action. The European Union has implemented environmental policies, specifically the Seventh Environment Action Program, that they are hopeful will bring a change to our warming world.

In 1997, the Treaty of Amsterdam was a catalyst for the European Union's involvement within environmental policy. In general, the treaty created a qualified majority vote in the European Council with co-decision rights in the European Parliament to make environmental policy decisions. Since the adoption of the treaty, environmental policy created by the European Union has noticeably grown. Today, environmental policies have become one of the most active areas within the European Union policy-making realm. The EU has some of the world's highest environmental standards (European Union, 2017). Like the United States countries belonging to the European Union are some of the largest energy consumers and greenhouse gas emitters in the world. However, unlike the United States, the EU has reacted to this with an increase in policy revolving around climate change.

Over the past few decades the European Union has been working tirelessly to develop and establish a broad range of environmental legislation. Since 1973, the European Union has created environmental programs, known as Environment Action Programs (EAP). Since the European Union has considered these programs to be successful, they are currently in the midst of the seventh action program. These programs provide "a framework for Union action in the field of the environment" (European Parliament, Council of the European Union, 2013). Established in January of 2014, the Seventh Environment Action Program is guiding the European Union's environmental policy until 2020. Even beyond 2020, this EAP has created a vision into 2050. The EEA is looking forward to living in a green economy. This green economy has been defined by the EU "as one in which environmental, economic and social policies and innovations enable society to use resources efficiently — enhancing human well-being in an inclusive manner, while maintaining the natural systems that sustain us" (European Environment Agency, 2012).

As evidenced above, it is clear that Europe is making strides toward maintaining a sustainable lifestyle. Europe acts as a great model for the United States to learn from. Currently in the United States, activist groups dominate progressive movements for environmental awareness. In 2014, along with China and the European Union, the United States ranked second in the top 3 biggest contributors to greenhouse gas emissions (See Figure 2). Therefore, it is imperative that the United States becomes a world leader like the EU with implementing effective change toward our warming world. Unfortunately, necessary actions are not taking place within the United States government. For example, President Trump removed the United States from the Paris Climate Accord. The Paris Climate Accord is an agreement within the United Nations Framework Convention on Climate Change that deals with greenhouse gas emissions mitigation, adaptation, and finance starting in the year 2020.

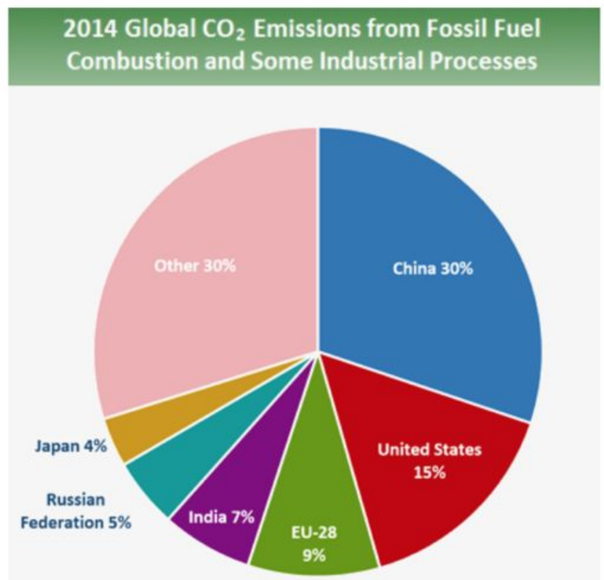

Figure 2

Source: Boden, T.A., Marland, G., and Andres, R.J. (2017). National CO2 Emissions from Fossil-Fuel Burning, Cement Manufacture, and Gas Flaring: 1751-2014, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, doi 10.3334/CDIAC/00001_V2017.

Removing the United States from an agreement like this weakens our chances at being frontrunners for saving the world against global warming. Climate change is a long-term challenge that requires sustainable global action. However, with the the United States being such a large contributor of emissions to our dwindling environment, there is increased pressure on voluntary efforts from federal, state, local, and corporate levels.

The United States Environmental Protection Agency claims that they are "taking a number of common-sense steps to address the challenge of climate change" (US EPA, 2016). Their many initiatives involve collecting emissions data, getting reductions, evaluating policy options, costs and benefits, advancing science, and partnering with states, localities, and tribes. Collecting various types of greenhouse gas emissions (GHG) data helps policymakers understand and identify opportunities for proposing regulations to help better reduce emissions and increase efficiency. Examples of reducing GHG emissions and successful partnerships are seen in the Clean Power Plan (CPP). The CPP was established to help address emissions from power plants. According to the EPA, when the Clean Power Plan is fully in place by 2030, carbon pollution from the power sector will be reduced to 32 percent below levels recorded in 2005. Through voluntary energy and climate programs, EPA's partners reduced over 345 million metric tons of greenhouse gases in 2010 alone (US EPA, 2016). Overall, the EPA is making monumental moves toward leading the United States to become more environmentally aware with numerous actions and legislations explained above and available on their website. However, without federal government support, these initiatives can only go so far.

College Campuses as Model Communities

Although the United States EPA is making strides to preventing climate change, colleges and universities across the nation have become extremely proactive in the environmental movement as well, as shown by the establishment of the American College and University Presidents' Climate Commitment. The program was created to address climate change, reduce GHG emissions by colleges and universities, drive research, and promote education (Jo, Ilves, Barth, & Leszczynski, 2017). New generations of students understand there is a problem that needs to be solved. As mentioned in the Social Context, competitiveness among colleges and universities places pressures on institutions to make sure that their campuses are exhibiting visible signs of sustainable and environmental initiatives on their campuses. Colleges and universities believe that installing solar photovoltaic systems on their campus will visibly display their institution's commitment toward sustainability. "From an aesthetic point of view, a solar PV system on campus creates an impression of a forward thinking and green institution for students, faculty and visitors" (Jo et al., 2017). These green campuses serve as examples of model living and learning communities. "University sustainability is moving further into the mainstream every passing year" (Goldfarb, 2016).

Examples of higher education institutions that have taken the necessary steps to transform their campuses include: Northwestern University, Drexel University, University of Arizona, Butte College, University at Buffalo, Colorado State University, Princeton University, University of Tennessee, Knoxville, and Santa Clara University. Many of these programs were faculty/student led-initiatives. Specifically, this report analyzes the efforts made by University of

Utah, Endicott College,University of Missouri-Kansas City , and William Paterson University below.

In 2015 the University of Utah not only completed their seventh rooftop solar panel installation on campus, but they were also the first university in the country to sponsor a community solar program that helped 380 homeowners commit to solar installations on their homes. The university teamed up with Utah Clean Energy, a local nonprofit, to provide discounts, credits, and know-how to U of U community members, making the installation of 1,800 kilowatts of solar panels on local residences a reality (Baker, 2016). (Shown in Figure 3)

Figure 3: Two of the solar arrays on the west penthouse of the J. Willard Marriott Library, University of Utah. *Source: https://unews.utah.edu/red-goes-for-green-energy/*

Other specific examples of a solar implementation on college and university campuses can be seen at Endicott College in Massachusetts. After looking into solar and other types of renewable energy technologies, administrators decided to install a solar canopy over a 255-space parking lot in 2014. Due to the success of the solar canopy, in 2016 the school designed and built a new hockey arena that included solar panels on the rooftop. At the University of Missouri-Kansas City, the institution's performing arts center had solar panels installed on the rooftop as well. Since the performing arts center was a new building that the school knew could bear the load of holding solar panels, it was also the university's highest energy using building on campus. Lastly, William Paterson University in New Jersey implemented solar panels on their recreation building due to its higher-energy-use and location next to a parking lot. The solar panels generate significant energy for the building and the parking lot (Helmerm, 2017).

The director of programs for the Association for the Advancement of Sustainability in Higher Education (ASSHE) describes the trend of implementing solar panels on college campuses as "widespread and growing quickly." The organization is aware of 330 institutions that have deployed more than 600 installations nationwide, with the total solar capacity in higher education at approximately 247,776 kilowatts" (Helmerm, 2017). Aside from making an impact on their own campuses, many of these institutions play a major role in spreading their environmental initiatives to their surrounding communities as well.

Policies

While in Europe, the EU is heavily influenced by activists; politicians consult with experts and activist groups before making decisions based on subjects they are not specialized in. In the United States, lawmakers are the primary decision makers. However, activist groups and higher educational institutions are able to take matters into their own hands in making the difference they want to see that lawmakers do not provide. Institutions are free to adopt their own sustainable plans for their campuses.

Pennsylvania Policies

After speaking with Lafayette's Office of Sustainability Energy Manager, Nick DeSalvo, we were informed of Pennsylvania's low energy costs. Advised by Lafayette's Director of Sustainability, Marie Fechik-Kirk, we were given possible grant policies that are available to higher educational institutions that would be reasonable for Lafayette College to consider being an institution situated in Pennsylvania. After our discussion with Marie, she believes that if the college is going to install solar panels on campus, grant funding or achieving a Power Purchase Agreement (discussed in greater detail in the Economic Analysis) would be critical for success.

Two possible grant policies are EBSCO's Solar Grant and the West Penn Power Sustainable Energy Fund. EBSCO Information Services is an American company that specializes in informations services as it is the leading discovery service provider for libraries worldwide. EBSCO Information Services has renewed its commitment to helping libraries "go green" by bringing back an expanded version of its EBSCO Solar Grant Program for 2017. As part of the EBSCO Solar initiative, EBSCO is currently seeking grant applications to help libraries fund solar installations. EBSCO is making two $100,000 grants available to bidders that will allow the winning libraries to reduce their utilities expenditures and install a solar array at their institution. In 2016, EBSCO awarded its first EBSCO Solar Grant to Austin Community College District's Highland Campus Library in Austin Texas (EBSCO Industries, Inc., 2017).

Another possible grant could come from the the West Penn Power Sustainable Energy Fund (WPPSEF). The WPPSEF is a nonprofit organization whose mission is to promote the use of renewable and clean energy technologies, energy conservation and energy efficiency technologies, and the education of those technologies that can benefit West Penn Power (WPP) ratepayers. WPPSEF grants are limited to non-profit entities, which works to Lafayette's benefit. However, obtaining a WPPSEF grant is a very competitive process where applicants must clearly demonstrate that their project will benefit WPP ratepayers (West Penn Power Sustainable Energy Fund, 2017). Therefore, in order for Lafayette to earn a WPPSEF grant, the college would need to provide information proving that there is a substantial amount of students that attend Lafayette from this area of Pennsylvania.

Lafayette's Current Environmental Commitment

"We are dedicated to creating a sustainable environment that improves the quality of life for all." - Lafayette College

Lafayette College is the only college/university in the Lehigh Valley to have signed the American College and University Presidents Climate Commitment. As stated previously, the American College and University Presidents Climate Commitment is an initiative aimed at addressing climate change, reducing greenhouses gases from colleges and universities, driving research and promoting education in this field of study. Since signing in 2008, Lafayette has developed a Climate Action Plan for reducing its carbon footprint. The Plant Operations Energy Committee's main job is to minimize the college's water and carbon footprint. Recently, the Committee published an Energy Policy that outlines the steps necessary for the College to reach energy saving goals. The Campus Energy Policy states "that all new construction and major renovations will meet Leadership in Energy and Environmental Design (LEED) silver standards for sustainability and green architecture" (Lafayette College Office of Sustainability, 2017a). The Campus Facilities Master Plan addresses numerous sustainability initiatives, such as:

> restoring native plants, reducing the amount of turf on campus, eliminating roadways, encouraging walking, biking and mass transportation, a recycling strategy, a dedication to composting, and a guide to organic farming and Good Agricultural Practices at LaFarm. Lafayette's current dining services provider, Bon Appetit, also provides formal policies that focus on local, sustainable food (Lafayette College, 2009).

The "Greening Lafayette" initiative focuses on raising awareness of sustainability and topics such as food, water, energy and waste. "Greening Lafayette is a module within Lafayette's Connected Communities Program (CCP), and it aims to bring the community together to engage with environmental issues, through education and action" (Lafayette College Office of Sustainability, 2017c). Comprised of administrators, faculty, and students, the Sustainability Committee is led by Marie Fechik-Kirkt. The Committee meets once a month to discuss campus sustainability initiatives and "facilitate communication and collaboration among groups committed to environmental protection and sustainable growth and development" (Lafayette College Office of Sustainability, 2017d). With Lafayette's Office of Sustainability, multiple ECOreps and student Green Guides serve as peer environmental educators on campus. In addition to the workings of Lafayette's Office of Sustainability, there are numerous student organizations committed to sustainability, both on and off-campus. Organizations include: Lafayette Environmental Awareness and Protection (LEAP), Lafayette Food and Farm Cooperative (LAFFCO), Society of Environmental Engineers and Scientists (SEES), Landis Community Outreach Center partnering with the West Ward Neighborhood Partnership Program, Nurture Nature Center and the Easton Farmers Market, and Engineers Without Borders (EWB).

These organizations and committees mentioned above, especially the Office of Sustainability, are key stakeholders in providing information necessary for the College to understand and to be knowledgeable of. After speaking with Professor Mary Wilford-Hunt, Lafayette College's Director of Facilities Planning and Construction, she informed our group that funding plays a major role in the implementation process as well.

Conclusion

As evidence in this section of the report, there are many elements that are to be considered in order to support the need for visible signs of renewable energy sources on Lafayette College's campus. On a global scale, the United States can learn from the environmental efforts being undertaken by the European Union. In the meantime, higher educational institutions will continue to be model living and learning communities for their local communities as well as national policymakers. Over the past few years, Lafayette has been making notable strides to creating a sustainable and environmentally aware environment. However, due to the emerging environmental awareness movement, the need for visible signs of renewable energy sources are needed to compete with other institutions across the nation.

TECHNICAL ANALYSIS

Introduction

The following section will go into the technical analysis of the implementation of solar energy on Lafayette College's Campus. The analysis will aim to provide a technical background on the usage of solar energy as a renewable energy source. The section analyzes two different types of solar power, how they function, noticable differences and then ultimately provides Lafayette with a recommendation for which panel would be most optimal at Lafayette College. Next, the section will look into the returns on energy from solar panel usage. Through calculations, quantifiable metrics on the amount of energy that can be used by facilities on campus will be determinable. Next, six different potential locations will be analyzed for housing solar energy. Several variables must be met in order for a building to be able to hold solar panels.

Lastly, the research will focus on three locations on campus and how these locations meet the criteria needed to house solar energy.

Solar Panel Analysis

Every year the Earth receives around $1.5x10^{18}$ kWh of solar energy, making it by far the most abundant energy resource available to mankind in our existence (Crawley, 2016). One of the ways the energy of the sun can be harvested and then used is through photovoltaic panels. A French physicist, Alexandre-Edmond Becquerel, discovered photovoltaic panels in 1839 (Crawley, 2016). Since then much advancement has been made in photovoltaic technology and currently it is one of the most widely used methods to harvest energy from the sun. A photovoltaic cell works by directly transforming solar radiation into electrical energy through the PV effect without any thermal cycles, mechanical cycles or chemical reactions (Crawley, 2016). The photovoltaic effect or the PV effect occurs when two dissimilar materials in close contact produce an electrical voltage when under contact of radiant energy (Encyclopedia Britannica, n.d.). A photovoltaic panel is separated into two silicon layers, the top layer with phosphorus to create a negative charge and the bottom layer with boron to decrease the amount of electrons to create a positive charge (Newton, 2015). When a photon hits the panel an electron is knocked out of the silicon junction. This electron is then collected with a metal conductive plate and then can flow like any other energy source (Crawley, 2016). Photovoltaic is known as one of the most effective forms of solar energy but there is another alternative that could be feasible to implement at Lafayette College.

Solar thermal is another form of solar energy that can be used as a renewable energy source. Solar thermal concentrates solar radiation as a source of heat to generate a hot fluid for a downstream energy conversion process (Crawley, 2016). Solar thermal can be used to produce electricity, solar fuels, or directly use processed heat (Crawley, 2016). In solar thermal systems the absorbed radiation will be turned into heat by the excited electrons falling back to their original energy level through energy transfers to the surrounding atoms (Mackay, 2015). In order to fully utilize solar thermal the incorporation of thermal storage is required. Through solar thermal, the suns energy can be leveraged to heat water that can then be used in a building for hot water. Furthermore, solar thermal can be particularly effective for buildings that require large amounts of hot water. Solar heaters for swimming pools are the most practical application (Lunde, 1980).

Photovoltaic Solar Thermal

Figure 1

Through a technical analysis to compare photovoltaic and solar thermal, three main advantages of photovoltaic came to light. First, photovoltaic cells are more economically feasible, and the price of panels continues to decline (J. Nicodemus, personal communication, 2017). In the past year the NREL reported that commercial solar PV system cost fell nearly 15%. Secondly, photovoltaic panels are more aesthetically pleasing, benefitting campus architecture, an important aspect for campus architect Mary Wilford-Hunt. Generally the low architectural quality characterizing solar thermal pinpoints as one major reason for the low spread of the technology. As confirmed by examples of photovoltaic, the improvement of the architectural quality can increase the use of a solar technology even more than price (Probst, 2011). The third main advantage of photovoltaic panels is that it requires minimal maintenance. For optimal efficiency the panels should be cleaned twice a year (J. Nicodemus, personal communication, 2017), while rooftop solar thermal panels and water tanks need regular maintenance to operate at peak efficiency (Energy.gov,). Because of the economic advantages, architectural benefits and low maintenance, photovoltaic panels are recommended as the best option for the Lafayette College feasibility study.

In order to fully realize the benefits of solar energy, Lafayette College must be able to calculate the returns on energy for photovoltaic panels. The main equation for returns on energy for photovoltaic panels is M_{pv}=. Where M_{pv} is the efficiency of photovoltaic panels, which is traditionally set at 15% (j. Nicodemus, personal communication, 2017). E_{pv} is the energy produced by the photovoltaic panels and E_{sol} is the energy from the solar resource (the sun). It is then derived that $E_{sol}=I_{sol}A_{pv}$, where I_{sol} equals the kwh/m^{2}day received in Easton, PA and A_{pv} is the area of solar panel receiving energy from the sun (J. Nicodemus, personal communication, 2017). Maps.nrel records that the average annual I_{sol} in Easton, PA is 4.43 kwh/m^{2}day. Therefore the final equation for return on energy for photovoltaic solar energy is M_{pv}=, where M_{pv}= 15%

and I_{sol}= 4.43 kwh/m^{2}day. The only unknown variable needed to calculate the return on energy for photovoltaic solar energy is the panel area that will be absorbing photons from the sun.

In order to fully optimize the returns on energy for photovoltaic solar panels it is important to angle the panel to optimize the amount of sunlight it receives. Photovoltaic panels work most efficiently when sunlight is hitting it perpendicularly. The optimal angle for photovoltaic solar panels is equal to the latitude of the location the panels are installed at. Crawley (2016) states, “it is generally accepted that the tilt angle that maximizes the annual energy collection is approximately equal to the latitude” (Pg. 53). In the case of Lafayette College the optimal angle for photovoltaic solar panels is approximately 40.7 degrees.

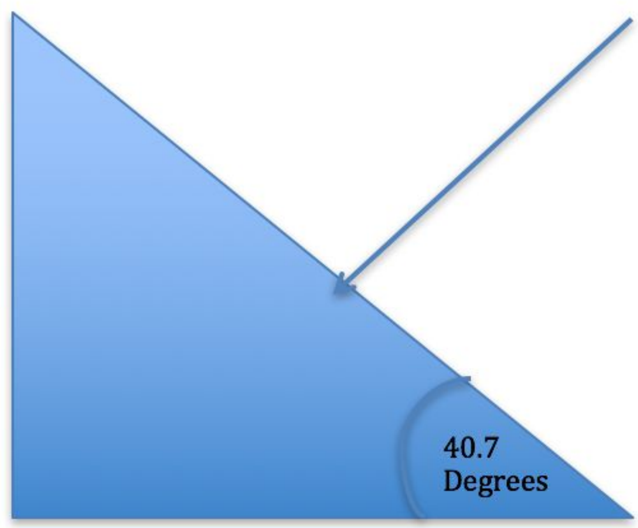

Figure 2

Another strategy used to determine the feasibility of installing solar panels at Lafayette College is to analyze efforts completed by other higher educational institutions. In 2014, Endicott

College installed a solar canopy over a 255-space parking lot (Helmer, 2017). Endicott College is located in Massachusetts, experiencing a similar climate to Lafayette College. In fact, Endicott has an annual smaller total solar resource than that of Lafayette College (Maps.nrel). The college reported the installations generated up to 12 million kilowatt hours of power per year, about 10 percent of total campus energy use, at a price lower than the school pays for natural gas (Helmer, 2017). Furthermore the Association for the Advancement of Sustainability in Higher Education reported that they are aware of 330 institutions that have deployed more than 600 installations nationwide, with the total solar capacity in higher education at approximately 247,776 kilowatts. College campuses across the country have successfully implemented solar energy systems and we strongly believe Lafayette College can follow in the steps of the 330 institutions before them and become a model institution for solar energy.

Location Selection

Another important step in determining the optimal location where the photovoltaic solar panels should be installed. Four criteria were set in order to rate each potential location on its feasibility to house photovoltaic panels. The first criterion is that the location must allow the panels to be south facing. Photovoltaic panels receive the most amount of direct sunlight when they are south facing (J. Nicodemus, personal communication, 2017). Related to this, the second criterion is that the panels must be placed in a location where they can receive direct sunlight. A location where they would be blocked by trees or other buildings would not serve as an optimal location for photovoltaic solar panels. It is crucial to balance the system size and visibility while not sacrificing the solar resource (Pratt, 2013). The third criterion is that the building must have the load capacity to hold photovoltaic panels. A common photovoltaic panel weighs between 15 to 17 kg/m^2, with the majority percentage of the weight coming from the glass followed by the aluminum frame (Crawley, 2016). In order to get details of load capacity for Lafayette College buildings our research team sat down with the Lafayette College Architect, Mary Wilford-Hunt. The final criterion is that the chosen building must allow the photovoltaic solar panels to be visible by pedestrians. As discussed is the social context section, visible solar energy is a top priority of our team. After analyzing several buildings on campus, three stood out.

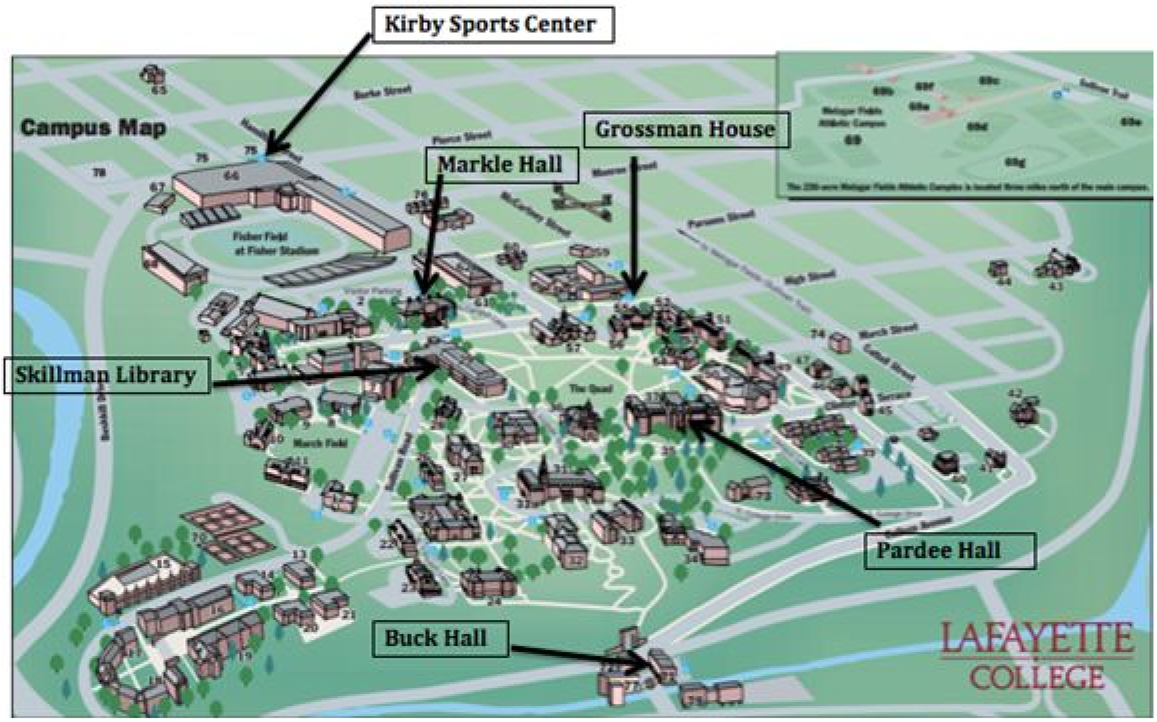

Figure 3

Building	South Facing	Load Capacity	Direct Sunlight	Visibility
Skillman Library	✓	✓	✓	✓
Markle Hall	✓			✓

Kirby Sports Center	✓	✓	✓	✓
Buck Hall	✓	✓	✓	✓
Pardee Hall	✓			✓
Grossman House	✓			

Figure 4

Figure 3, maps out six different potential locations across Lafayette Campus. The six are Skillman Library, Markle Hall, Kirby Sports Center, Buck Hall, Pardee Hall and Grossman House. As shown in the table above, three buildings meet all four criteria for being a location that can house photovoltaic solar panels. The three building are Skillman Library, Kirby Sports Center, and Buck Hall.

Figure 5

Figure 6

Figure 7

Figure 8

Skillman Library acts as the center point for the Lafayette Campus. It is one of the most popular buildings on campus and acts as a symbol for the college. Skillman Library does have the necessary load capacity to house photovoltaic panels (M.Wilford-Hunt, personal communication, 2017). Also due to its location on campus most students and visitors will be guaranteed to pass by the building daily. However the level of visibility for solar panels is in question. As shown the in figure 5, showing the front of the library, there is no clear perspective of the roof. Solar panels are placed at angles, which aids to their visibility on a flat roof. Figure 7, shows the perspective of Skillman from the steps of Farinon, where angled solar panels would be visible. In figure 6, showing the back of the library, there is improved visibility of the roof. Skillman does receive direct sunlight and is capable of hosting south facing solar panels at the recommended spots, outlined in figure 8.

Figure 9

Figure 10

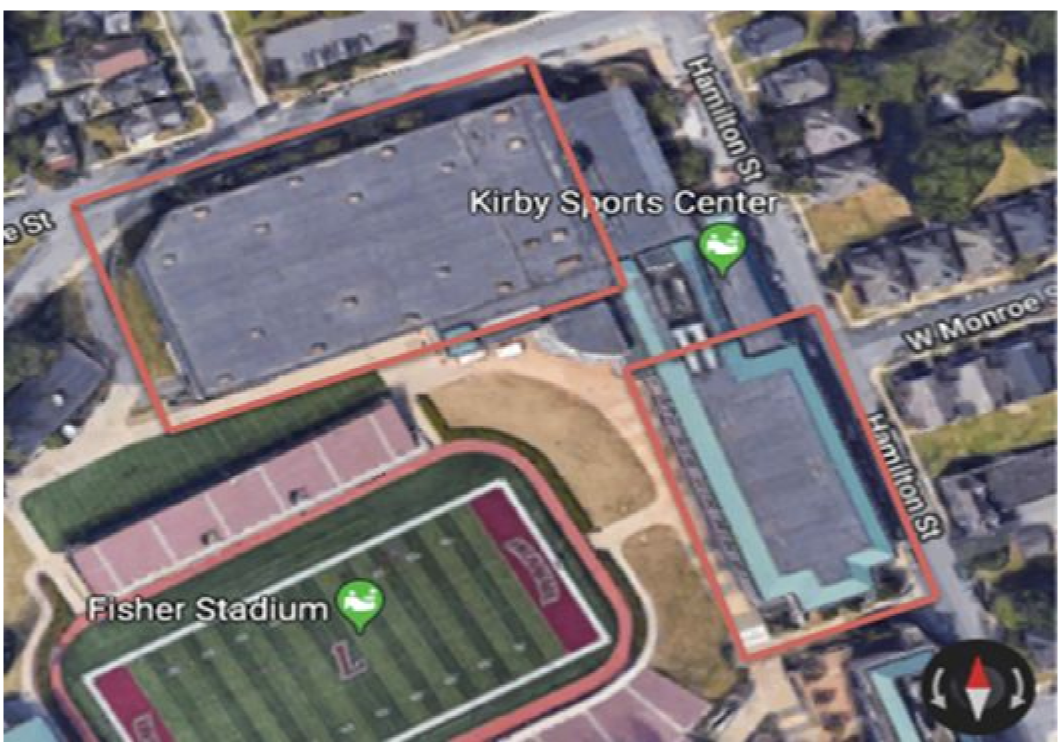

Figure 11

The second building that met all four criteria is Kirby Sports Center. Kirby Sports Center is especially attractive because it will allow for visible solar energy that can be seen from football games and other populated athletic events at Fisher Field, as shown in figure 10. Also figure 9 shows the vantage point from the Markle parking deck, a common parking place for prospective students. Furthermore, Kirby Sports Center has the load capacity, no obstructions from direct sunlight and plenty of area to house solar panels. (M.Wilford-Hunt, personal communication, 2017). The outlined recommended housing space, shown in figure 11, will be visible to those in the stadium and from Markle Parking deck. As a large athletic facility, the Kirby Sports Center requires energy that could be harvested through the sun instead of burning fossil fuels.

Figure 12

Figure 13

Figure 14

The third and final building that met all four criteria is Buck Hall. Located down the hill, Buck Hall acts as a welcoming entity for all those entering the Lafayette College Campus (Figure 12), allowing for visible solar energy that can achieve the goals stated in the social context section. From College Hill, the roof of Buck Hall is easily visible as one uses the stairs to access downtown Easton (Figure 13). This is especially notable because of future talks of implementing an elevator, only increasing the visibility of the Buck Hall's roof. Furthermore, it was discovered that Buck Hall is actually constructed to hold solar panels, but due to a lack of budget the plan never went through (M.Wilford-Hunt, personal communication, 2017). Therefore, Buck Hall meets all four criteria as a suitable building to house solar energy.

Conclusion

Through the technical analysis performed, the research team analyzed different solar energy methods, how to fully optimize solar energy and where Lafayette Campus should house solar panels. The technical analysis performed is a start to Lafayette College implementing solar energy on campus, however there are some next steps that would be beneficial to the further the process. First would be to exactly define the area of photovoltaic solar panels that would be installed. By doing so, Lafayette College would have more accurate metrics on how much energy they should expect from implementing photovoltaic solar panels. This is an important step in the process, because real metrics to show the returns on energy expected will aid in getting administration approval for a solar energy project. Further analysis of the buildings selected for optimal locations for photovoltaic solar panels could also be beneficial to the study. It will be crucial to place solar panels in visible areas of the roof of the selected building. Through a physical analysis of the roof more information can be collected on the area of photovoltaic panels that can be installed.

As a prestigious institution, Lafayette College is in the unique position to implement renewable energy on campus in terms of solar energy. In terms of the technical context, Lafayette College stands in a great position to move forward in the process of installing solar panels on campus. In the 21st century, photovoltaic technology has demonstrated the maturity to become a major source of power for the world (Crawley, 2016). With prime solar housing locations, along with advanced solar technology, Lafayette College is ready to continue the process to implement solar energy systems on campus.

ECONOMIC ANALYSIS

Introduction

This section analyzes the economic factors involved in the decision to implement solar panels on the roofs of buildings at Lafayette College. In this section we calculate what Lafayette currently pays for electricity on an annual basis. Subsequently, we detail our attempt to estimate the costs of installing solar panels on campus and compare our results from the two calculations. Our team believes there is added value that comes from the qualitative benefits solar energy systems would add to our campus that are difficult to account for in quantitative costs. That being said, in strict dollar terms, our estimated costs of implementing solar energy systems on campus are greater than what the College currently pays for electricity. We based our analysis of economic factors on common industry standards, best practices in project management, and communications with Lafayette faculty who specialize in renewable energy.

What is electricity used for on college campuses?

Electricity is a necessity for modern day life. Some of the major uses of electricity in the United States are lighting, heating, cooling, refrigeration and for operating appliances such as computers, electronics, and machinery (EIA, 2016). All of these components are crucial in order for Lafayette College to operate the way it does. College campuses are interesting in the fact that they host different types of buildings: residential buildings, dining halls, classrooms, science building, sports facilities, and libraries to name a few. At other universities, science buildings and recreation buildings use the most energy (Helmer, 2017). Lafayette is no different in this regard. As per the 2011 Climate Action Plan: "The most significant contributors to Lafayette's emission are the science and engineering buildings, Acopian Engineering Center and Hugel Science Center, and the Kirby Sports Center, which require large volumes of conditioned air" (Lafayette College, 2011).

What does Lafayette currently pay for electricity?

A good starting point in determining the economic feasibility of adding solar panels to roofs on Lafayette's campus is to consider what the school currently pays for electricity and compare it to what it might cost to add renewable solar systems. Lafayette's Campus Energy Manager, Nick Desalvo, assesses the College's kilowatt hour

Annual Electricity Cost				
	Year	kWh	Unit cost / kWh	Cost
	FY16	26,392,631	$ 0.0747	$ 1,971,529.54
	FY15	27,197,517	$ 0.0747	$ 2,031,654.52
	FY14	26,901,180	$ 0.0747	$ 2,009,518.15

Table 1: FY16 extends from July 1, 2015 to June 30, 2016.
Source: Nick Desalvo, Lafayette College Office of Sustainability

(kWh) usage each year. His office has documented usage for each of last three years, as well as the unit cost the College pays for that electricity. By multiplying the number of kWh used by Lafayette by the unit cost per kWh (also provided by The Office of Sustainability) we were able to estimate the College's annual costs for electricity, detailed in Table 1.

Lafayette's electricity usage has remained relatively constant over the last three fiscal years at about 27 million kWh. Costs of roughly 7.50 cents per kWh equate to an annual electricity cost of about $2 million for each of the last three fiscal years.

How much would solar energy cost Lafayette?

The price of solar energy systems has consistently dropped in recent years. Per the National Renewable Energy Laboratory's (NREL) September news release:

> The installed cost of solar power fell to record lows in the first quarter of 2017 because of the continuing decline in photovoltaic (PV) module and inverter prices, higher module efficiency, and lower labor costs, according to an analysis by the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) (NREL, 2017).

In order to calculate how much solar energy systems would cost to implement at Lafayette, we had to determine how much rooftop space would be available for solar panels. As discussed in the Technical Analysis, the most optimal buildings capable of supporting solar panels are Buck

Building	Size (ft^2)	Converted to m^2
Buck Hall	18,000	1,672
Kirby Sports Center	111,000	10,312
Skillman Library	75,000	6,968
	Total:	18,952

Table 2

Hall, Kirby Sports Center, and Skillman Library. By consulting campus floor plans, we found the square footage of each building and converted that number to square meters. Our findings are detailed in Table 2.

This calculation allowed us to estimate the number of kWh of electricity those panels could produce using the formula for returns on energy explained in the Technical Analysis. Equation 1 is detailed below.

$$E_{pv} = (.15)*(4.5 \text{ kWh/m}^2 \text{ day})*(18{,}952 \text{ m}^2)*(365 \text{ days}) = \sim 4{,}669{,}000 \text{ kWh}$$
$$\longrightarrow \text{17.7\% of the electricity Lafayette used in FY2016}$$

Equation 1

With 18,952 square meters of solar panels the school would be able to produce roughly 4,669,000 kWh of electricity, close to 18% of the total electricity it used in FY2016. Greenhouse gas (GHG) emissions from generating electricity by burning fossil fuels are on the magnitude of ten to twenty times greater than GHG emissions from generating electricity from photovoltaic systems in terms of grams of CO_2 per kWh (Alsema, de Wild-Scholten, & Fthenakis, 2006). Considering how many kWh of electricity Lafayette uses annually, and understanding that all of those kWh come at the cost of polluting the environment excessively, to be able to potentially get 18% of our electricity in a sustainable way is significant.

One thing to note: the estimated square meters of roof space available is based off of building floor plans. It is optimistic to assume that every square meter of floor space on the ground level is equal to a square meter of roof space, and every one of those square meters can host solar panels. Putting 18,952 square meters of solar panels on the roofs of Buck Hall, Kirby Sports Center, and Skillman Library is a best case scenario projection.

Next we estimated how much it would cost Lafayette to actually produce these 4,669,000 kWh of clean electricity. In order to do so, we used the levelized cost of electricity (LCOE) benchmarks reported by the NREL in September of 2017. The LCOE is one of the solar industry's most commonly used metrics. It takes into account the upfront project cost of implementing solar systems, which includes acquiring materials and installation, as well as lifetime operations and maintenance costs. The idea behind the LCOE is that it is supposed to be a 1 to 1 comparison of going solar versus staying on the grid (Bushong, 2016). Simplified, the LCOE is essentially equal to the lifecycle cost of a solar project divided by the lifetime energy production of that solar project. See Equation 2 below.

$$\text{LCOE} = \frac{\text{Lifecycle cost of solar project}}{\text{Lifetime energy production of solar project}}$$

Equation 2

In September, the NREL reported that the LCOE, excluding any subsidies for commercial solar systems, is between 9.2 and 12.0 cents per kWh (NREL, 2017). By multiplying the LCOE that the NREL reported by the 4,669,000 kWh of electricity a solar system on campus could produce we were able to estimate costs of implementing such a system, detailed below in Table 3.

Potential kWh	Unit cost /kWh (low)	Unit cost /kWh (high)	Cost (low)	Cost (high)
4,669,000	$0.092	$0.12	$429,548.00	$560,280.00

Table 3

Based off of our calculations, we expect it would cost between about $430,000 and $560,000 annually to get this renewable solar system on the roofs of Buck Hall, Kirby Sports Center, and Skillman Library. In terms of total costs, Lafayette could expect to pay between 4% and 10% more than what it paid in FY16. Again, this cost increase would allow Lafayette to produce 18% of its annual electricity needed in an environmentally friendly, sustainable way. If unit costs are on the lower end of that range, a 4% increase in costs is not all that much. It would equate to roughly $80,000 annually. Likely, the cost would fall somewhere in the middle of that range, and as stated in the introduction, having a renewable solar system would add value beyond what is taken into account in these quantitative estimates.

Qualitative Value

There is qualitative value that comes from implementing renewable solar energy systems on campus that is difficult to put a number on. Some of that qualitative value comes from doing the right thing. Implementing solar systems on the roofs of buildings can potentially allow Lafayette to produce 18%, almost a fifth, of its total annual electricity needs without burning fossil fuels. As stated previously, photovoltaic systems emit ten to twenty times less grams of CO_2 per kWh than burning fossil fuels (Alsema et al., 2006). The decision to add this type of solar system to campus would significantly reduce the school's carbon footprint. Lafayette confidently claims it is committed to being a sustainable campus. Its website reads, “We're working to cut global warming emissions, integrate sustainability into the curriculum, and cultivate solutions to ensure a healthier environmental future. Exploring sustainable living on campus prepares students for a life of environmental citizenship" (Lafayette College Office of Sustainability, 2017b). LEED certified buildings like Grossman House and the soon to be Rockwell Integrated Sciences Center prove this is the case. They are also examples of projects where the cheapest option was not the best option. Lafayette could have certainly had Grossman or Rockwell designed to be less expensive, but the school was willing to pay more for the environmental benefits that come from LEED certified buildings. That same logic should apply for decisions in how to acquire electricity. The environmental benefits that come from having a sustainable solar system on campus are worth the additional costs involved in making that system a reality.

Lafayette would receive educational benefits from adding a solar system to campus as well. Nicholas Pratt and Jordan Crolly from the Department of Energy & Mineral Engineering at The Pennsylvania State University wrote, "A photovoltaic array on a university campus can have a variety of educational benefits….There are many courses spanning several subject areas that could integrate the data generated by the solar array into their lesson plan. Courses ranging from business, to engineering, to liberal arts, could use this data in educational exercises specific to their courses" (2013). It would not happen immediately, but it does not seem unrealistic to believe future classes of students could benefit from analyzing these solar panels implementation and effects. Discussions about the construction of Rockwell Integrated Sciences Center have been a part of many engineering courses recently so there is no reason to believe the the installation of a photovoltaic system would not yield similar beneficial discussions.

There is also value that comes in improving Lafayette's image in the eyes of prospective students. Today's generation of students cares about the environment. When considering colleges, prospective high school juniors and seniors want to see sustainability efforts when they visit campuses. An article published on EnergySage stated:

> For many students in the modern era, especially in liberal urban environments, the prospect of going to a school or university that is seen as being sustainable and eco-conscious can be a distinguishing factor. Thousands of students seek out schools that will be the best environment to study sustainable practices and green policy, which makes solar-powered universities a very attractive option (Richardson, 2017).

Staying competitive is especially important right now for Lafayette, as the school has plans to increase its size in the coming years. If adding solar panels to roofs on campus truly has an impact in students decisions on where to attend college, then not implementing these types of systems would hurt Lafayette in the increasingly competitive landscape of admissions. Other top schools that Lafayette competes with for students are starting to add solar systems to their campuses, and it is only a matter of time until it is the norm. Getting solar panels on campus before it becomes standard will help Lafayette continue to bring in strong classes of students, and the value generated in doing so helps offset slightly higher energy costs.

Tax Incentives and Subsidies?

Most homeowners, businesses, and other corporations receive some sort of tax incentive or other subsidy when making the switch to solar systems that offset some of the costs incurred when doing so (Energy.gov, 2017). These incentives can make the LCOE for solar energy equal to or even less than grid costs. Unfortunately, non-profit organizations do not qualify for most of these subsidies. In conversations with Professor Wilford Hunt, she confirmed that Lafayette operates as a non-profit and is incapable of attaining the potential tax benefits that exist for implementing a solar system. However, as described in the Political/Policy Context, there are a few specific grants Lafayette could apply for. Notice that in the LCOE range discussed above we specifically mentioned that it is excluding any subsidies.

Non-profit organizations can indirectly receive a financial subsidy from adding solar systems in the form of power purchase agreements. Per the Environmental Protection Agency, "A Solar Power Purchase Agreement (SPPA) is a financial arrangement in which a third-party developer owns, operates, and maintains the photovoltaic (PV) system, and a host customer agrees to site the system on its property and purchases the system's electric output from the solar services provider for a predetermined period" (US EPA, 2016). Essentially, the third-party provider would own the solar system on Lafayette's campus and receive tax incentives because it is not a non-profit organization. Lafayette would indirectly receive some amount of those incentives because the school would theoretically pay less money per kWh for the electricity it purchases from the third-party provider. According to the Office of Sustainability, Lafayette has actually looked into how feasible a PPA would be. However, it is unclear how seriously the school has considered it and how comfortable the school would be hosting a solar system that it did not own or maintain.

Conclusion

There are multiple things to consider from an economic standpoint when thinking about the feasibility of adding solar panels to the roofs of buildings on campus. The cost of solar energy has been falling every year, but as detailed above, is still more expensive than for

Lafayette to stay on the grid. We estimate that Lafayette's total annual costs would increase between 4% and 10% compared to what they paid for electricity in FY16 if they added solar systems to the rooftops of Buck Hall, Kirby Sports Center, and Skillman Library. That increase in costs would allow the school to produce 18% of the energy they need annually in a sustainable way. The qualitative benefits that come from implementing a solar system of this nature, such as reducing our carbon footprint, educational possibilities, and becoming a more enticing college in the eyes of prospective students make up for this difference in costs.

CONCLUSION

Conclusions

The Social Context section presented the broader contexts that shaped and affected our entire project. The ultimate driving force for this project is the looming threat of climate change. This global issue has put pressure on nations around the world to invest in renewable energy and put a focus back on the environment. As a result, a green movement across the country and colleges all around the United States are getting on board. With such a big emphasis being put on the environment, colleges want to make sure that they are providing their students with the tools and experiences to help the world. Lafayette College should aim to continue to be competitive in this regard, and visible renewable energy efforts on campus are sparse. With the implementation of solar panels on rooftops, Lafayette could bolster its attractiveness to prospective students while investing in renewable energy.

The Political/Policy Context section provided information on how the United States can better implement environmental policies throughout the nation by looking at the European Union as an example. For now, environmental activists and college campuses are the leaders of the country's environmental movements. College campuses act as great model communities and have the potential to impact their local communities. In recent years, Lafayette has been making strides that display the college's commitment to sustainability. Through various student and faculty-lead organizations and initiatives, LaFarm, and the newly established Office of Sustainability, Lafayette is demonstrating their environmental awareness efforts. However, we feel that these initiatives are not well represented to students, both current and prospective. Therefore, implementing visible solar panels on campus would be a great way to prove and show Lafayette's current efforts.

The Technical Analysis section displayed three main advantages of photovoltaic panels over solar thermal panels. Photovoltaic panels are economically more feasible, aesthetically pleasing and require little maintenance. The technical analysis defined south facing, visibility, load capacity and direct sunlight as the four criteria to rate locations. Skillman Library, Kirby Sports Center, and Buck Hall met all four criteria and therefore are the final recommendations for housing solar energy.

The Economic Analysis section concluded that the qualitative value that would come from implementing a solar system on campus offsets the extra cost Lafayette would incur from doing so. Our estimates were optimistic; however, they still show that it is possible to provide for over a tenth of Lafayette's current energy use through solar energy. It also discussed the possibility of saving additional money if we were to engage in a power purchase agreement with a third party to get access to the tax incentives offered for solar energy systems.

Recommendation

After analyzing the four sections of this report: social, political/policy, economic, and technical, we have determined that Lafayette College should continue researching the feasibility of adding solar energy systems to campus, with a focus on the roofs of Kirby Sports Center, Skillman Library and Buck Hall as potential *visible* locations.

Moving Forward

We hope that the analysis and recommendations presented in this report will help the efforts of Lafayette's Office of Sustainability in "greening Lafayette" to become a more sustainable environment. With this report, we hope that the Office of Sustainability will use it as a guide for implementing the use of solar panels on Lafayette's campus. The figures that we came up with were estimates, where we looked at the best case scenario in most situations. Bringing professionals to campus to provide actual quotes of what it would cost Lafayette to install this type of system would help to make a more convincing case, backed with actual costs. This process would include determining which buildings are actually able to bear the load of photovoltaic panels, and figuring out exactly how much roof space is available on each of these buildings to host panels. With that information, a better estimate of how much energy the panels would be able to actually produce could be made. Exploring the possible grants and power purchase agreements would also go hand in hand with this. Future groups should look into whether it would be better for Lafayette to install solar panels on its own or use a third party provider to take advantage of potential tax benefits. This would require the school to obtain cost quotes from potential third-party PPA partners, alongside the quotes discussed above. If this were successful and implementing solar panels becomes a reality, the next step would be to determine which building exactly would be the best option to implement solar panels or if all of them would be a realistic expectation. Starting with one building and seeing how it plays out would also be an alternative. Costs per kWh would likely be negotiable depending on the size of the project and the vendor, which is why Lafayette should consider price quotes from multiple firms. From a political and social perspective, there is no argument to be made against implementing this type of system on campus. That is why the biggest step moving forward is to improve the precision and accuracy of the technical analysis, as well as convince the decision makers at the college that this project is economically worth while.

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