Feasibility Report of Microgrids at Lafayette College

EGRS Engineering & Society Capstone 451

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Introduction

Lafayette College is currently committed to its own climate action plans which aims "to develop a comprehensive plan to achieve climate neutrality as soon as possible." (18) More specially the college has announced its plan "to reduce Greenhouse Gas emissions 20% from 2007 levels by 2021." (18) The motive for Lafayette's Climate Action Plan is twofold. First the school wants to do its share in reducing Greenhouse Gas emissions to diminish the school's effect on the world climate. The city of Easton has its own climate action plan, substituting federal or state requirements, obligating the city to reduce its emissions. If Lafayette acts quickly it can be a beacon for clean energy for the rest of the city. The second is to remain competitive with other schools, like Princeton University and Dickinson College, which currently generate their own, emission free energy.

In addition to greenhouse gas emissions, Lafayette College is also susceptible to power outages, like that in the fall of 2016. If the college was to become energy independent it could not only ensure energy security for the college, but assist the city of Easton in the event of widespread power outages. The thousands of students at Lafayette are solely dependent of the College's power supply and any power outage could leave all of them stranded without electricity.

In order to achieve Lafayette College's goal of achieving carbon neutrality by 2035, Lafayette College is looking at multiple projects to increase the sustainability of the school. One of said projects is a microgrid that takes advantage of renewable resources that can be implemented on campus. Before diving into the possibility of using a microgrid all across campus, a smaller microgrid that could be placed in Anderson Courtyard to give the cluster of buildings their own microgrid. Anderson Courtyard is home to many of the colleges most energy intensive buildings, and creating a trial microgrid there could be used to measure the effectiveness of implementing a microgrid across the rest of Lafayette's campus.

A microgrid is a power grid with the capability of disconnecting from the larger electrical grid, as well as the ability to use renewable resources for energy. These are the main features of a microgrid but there are also many other benefits of creating one. For example, easily identifiable issues when part of the system were to fail. Also the ability for the rest of the system to continue providing power to other areas even when part of the microgrid is experiencing issues. Compared to the larger macrogrid where a power line goes down and an entire area is left without power. The ability to keep providing power to the rest of the microgrid even when a part of it is experiencing issues is an incredible benefit. Overall the benefits of creating a microgrid are immense which is the reason why Lafayette College should look into the possibility of implementing a microgrid on campus.

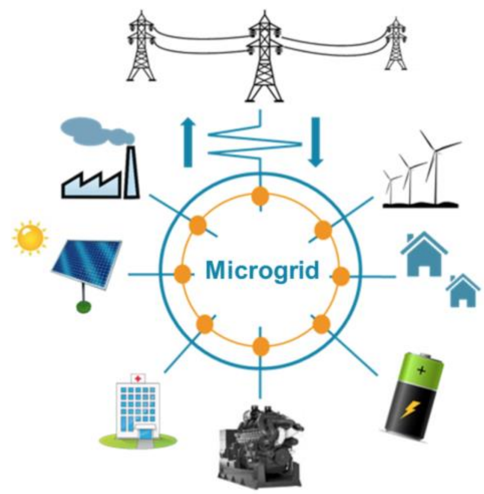

Figure 1: The basic set up of a microgrid, with the controller determining when to connect and disconnect from the macrogrid and when to relying on other methods of power generation or storage

Implementing a microgrid on Lafayette's campus does not come without certain challenges. To start, there are multiple political factors that will decide whether this microgrid will actually be implemented on campus. There are multiple options that the college is currently weighing in order to order to achieve carbon neutrality and stay competitive with similar schools.

The Board of Trustees must be persuaded for the implementation process to commence. The Lafayette community also needs to be involved in the implementation process in order for this microgrid to remain sustainable long-term. Funding is not as much of a challenge for microgrids, as the college and the board of trustees have made a commitment to reducing the environmental impact of Lafayette and have made it clear that they will spend the necessary funds. On the technical side, one of the biggest challenges facing the microgrid is finding the space necessary for the energy sources used for the microgrid, specifically with solar panels. Even just to power the Anderson Courtyard, the college would need an extensive amount of roof space. These buildings also need to be compatible with any of the new green technology implemented with the microgrid. Energy also needs to be stored effectively when there is excess energy being produced.

These challenges can be overcome. With communication and the politics surrounding microgrids it only takes consistent and full sharing of key concepts and knowledge about microgrids to those that do not have a full understanding. The only way that a microgrid will be used is if those in charge of the climate action plan, the board of trustees, see it as adding value and furthering Lafayette towards its goal of reducing emissions and staying competitive with rival schools. The challenge of achieving funds is more of a return-on-investment question. Adding a microgrid would be costly up front for the installation but would have the opportunity for a cash flow for the college by selling energy and reducing energy costs. The Lafayette community can benefit directly from having an installed microgrid on campus as well as indirectly by providing students the opportunity to learn about green energy and the grid itself. The space used for setting the infrastructure up would not interfere with day to day life as well, ensuring that Lafayette students are not losing aspects of their normal college experience. Some buildings may not be suited for a microgrid due to the structural integrity of the building or the roof design. To overcome this, it is essential to understand each building's structure, weight limits, and floor plans for effective implementation. These questions of Lafayette's existing electrical grid and infrastructure being able to handle a microgrid are able to be addressed by simply looking at what is already in place as well as the addition of this system would not be a burden on existing electrical infrastructure.

Social Context

Why are we looking at microgrids?

In the past decade there have been global strides to address climate change as it becomes an ever larger problem. Greenhouse gases (GHGs) are one of the main causes behind this change and are motivating smaller communities and groups to make changes (IPCC 2018). The Lafayette Climate Action Plan developed in 2011 and recently overhauled in the fall of 2018 exemplifies the commitment Lafayette has made to the Lafayette community. This plan addresses the ACUPCC's (American College and University Presidents Climate Commitment) focus on reducing greenhouse gas emissions. The ultimate goal of this commitment is carbon neutrality by 2035 (Lafayette College, 2011). Lafayette's Climate Action Plan (CAP) outlines "specific strategies to ultimately lower greenhouse gas emissions (GHGs) and achieve climate neutrality" (Lafayette College, 2011). These strategies have been implemented in stages, starting with energy conservation measures (ECMs) to ultimately lower Lafayette's GHG emissions in the future (Lafayette College, 2011). In October of 2018 the board of trustees were presented with a revised climate action plan with modified goals. One of the goals, zero emissions by 2035, may seem ambitious but there have been over 20 alternatives identified for reducing campus emissions that could help Lafayette achieve zero emissions. Microgrids are one alternative that can address emissions problems on campus. Microgrids offer Lafayette several benefits, namely emissions reductions and energy security.

Microgrids facilitate zero emissions, something various other colleges have already been working towards (Farzan, 2013). Lafayette has the capability to compete with these schools such as Trinity College and Dickinson College who have installed microgrids on their respective campuses (Hermes, 2018, Lyons 2014). There are other colleges and universities, like University of California at San Diego, that have developed their own microgrids and are researching more efficient methods to run microgrids, (Washom, 2013). Lafayette's competitors are taking steps towards carbon neutrality, and alternatives like a microgrids, giving Lafayette an opportunity to catch up.

Another benefit microgrids would provide Lafayette is their convenient implementation on campus. Lafayette's infrastructure is aging and inefficient, making the emissions problem worse. Updating the steam heating infrastructure with a combined heat and power plant controlled by a microgrid could help alleviate these emissions problems by increasing overall efficiency. Besides combined heat and power, microgrids are able to be installed with most other green energy alternatives like wind, solar, or distributed energy resources. The adaptability of a microgrid enables it to encompass multiple different energy sources. Microgrid have the ability to operate "off the grid," or, in island mode. Being able to function as an island allows Lafayette to have a secure power source. This energy security would allow Lafayette to maintain critical functions like heating and power during crisis situations and allow students to stay safe.

Decentralizing the power source allows the buildings in the microgrid to act independently, so the college gains control over its power.

Installing a microgrid will have long term impacts on the college with monetary savings and competing with other schools. Microgrids could attract new students who may be interested in grid engineering, alternative energies, or power generation. A microgrid and other sources of clean energy generation will allow Lafayette to open up new courses in energy management with the opportunity to work on Lafayette’s microgrid. This could attract more students and add educational opportunities to Lafayette’s students. Therefore, a microgrid can intrinsically benefit Lafayette’s community. Intrinsic social benefits are benefits to the community that are not assigned a monetary value. Important social benefits can persuade prospective students to view Lafayette as a more sustainable community, competing with other schools and opening up the possibility of more donations from alumni who support this cause. This means that alumni can help to fund the installation costs and become more involved in emissions reduction at their alma mater. Social benefits are hard to assign a real monetary value to because they are uncertain, but they have the capability of having a real impact. Non-market values would have a long term pay off for the college and could do a lot to make a better school image as well as address the Climate Action Plan. Being ‘intangible externalities’ means Lafayette would have to assign its own values to these attributes.

Lafayette College’s emphasis on the Climate Action Plan to change to no emissions by 2035 means that there is a social cost of carbon being accounted for. One of the largest social costs to grapple with in any talk of emissions reduction is the social cost of carbon. The reason we want to look at the social cost of carbon is because the market omits it while it still contributes to climate change, and can have a large impact on the decisions the college will make

(Parker, 2018). An outline for creating a cost of carbon created by Ms. Parker at Smith College is an example of the emphasis placed on carbon emissions as a real cost to account for. Parker was able to internalize the social cost of carbon and view it in a financial setting. Including this cost will allow the college to judge each alternative fairly with what the current energy supply situation is. Microgrids will only help reduce emissions as well with the capability to use both on site power and utility power depending on demand.

In the past, Director of Facility Operations, Bruce Ferretti was able to bring up natural gas-based-microgrids to the board of trustees, but infrastructure and 3rd party barriers halted any advance (Ferretti, 2018, Hayes, 2018). A natural gas fed microgrid is possible, but that is outside the scope of the Climate Action Plan as well as require UGI, Lafayette's natural gas provider, to invest in updating natural gas infrastructure. The Climate Action Plan calls for a reduction in emissions, and a switch to green energy sources (Lafayette College, 2011). Natural gas is viewed as a 'cleaner' fossil fuel, but there are still emissions. The existing infrastructure at Lafayette would support natural gas fed power, but while natural gas is a more efficient fuel source, natural gas is not a renewable energy. Feasibility of this goes up when it is applied in a combined heat and power (CHP) setting.

Combined heat and power systems could use this and reduce costs of implementing new infrastructure. Combined heat and power uses excess heat from power generation to heat up water, or another heating substance, to heat buildings. This makes the power generation more efficient by taking the excess heat and put it to use for heating the buildings, making the inefficiency of power generation suddenly seem 'more efficient'. This fits well into the current infrastructure, and natural gas can be substituted for an alternative fuel such as gasified wood (Wallace 2010)

Microgrids differ from the macrogrid because they are more localized and easily changed. This flexibility allows microgrids to adapt to many different situations. Every state, county, and town has different social contexts that must be thought about before choosing the best microgrid option for that area. For Lafayette College, with the recent Climate Action Plan revision in late 2018 and the new goal of carbon neutrality by 2035, microgrids may make sense. Looking at the identities that make a location unique is the key to understanding the social contexts and knowing emissions and energy production sources may be up in the air helps to establish microgrids as a plausible part of the overall plan.

Microgrids have a variety of different technological options that can be used to meet specific needs of a the facility considering them. Lafayette is currently considering three types of microgrids. The first would provide solely backup power generation in case of emergency or need. The second option would be able to operate outside of emergency situations, and potentially buy or sell energy depending on need. The third option would provide power for the campus completely independently of the macrogrid. A microgrid at Lafayette can be used as a emergency response to ensure that critical processes like: power for lighting, heating, or air conditioning stay on during natural disasters or blackouts. In 2012, Hurricane Sandy hit the college, and facilities had to decide whether to continue operation and allow students to stay on campus or send students home due to the lack of power. This was an especially tough decision because while the power was out the college, the dorms lacked heat during the cold weather that moved in after the storm. Students were encouraged to go home to alleviate the load on the college and to ensure their safety. At the very least, emergency response systems could help to sustain critical processes on Lafayette during an outage. This emergency response would provide a sense of safety and energy security among the student body, as well as parents peace of mind during an emergency.

The second option is similar to the first type of microgrid except with demand response added. This would provide energy to the school in times of desperate need. The department of energy states that "Demand response provides an opportunity for consumers to play a significant role in the operation of the electric grid by reducing or shifting their electricity usage during peak periods in response to time-based rates or other forms of financial incentives." (energy.gov, n.d., 25). Demand response technology can reduce electricity prices for users by managing the supply and demand of energy. This type of microgrid will be economically beneficial and appealing to the College and stays in the scope of the Climate Action Plan. Demand response technology is meant to help add a dynamic to the microgrid that analyzes which areas have the most and least energy usage on top of energy audits that have already been done (Fechik-Kirk & DeSalvo, 2018). Students will play a big roll in this type of technology because they can help review this dynamic analysis of the demand for electricity in certain areas. Having this type of microgrid at Lafayette college will allow greater energy security and more data on how energy is used at the college.

The last option would be a microgrid that incorporates combined heat and power (CHP) technology. CHP is a specific type of energy production that incorporates the production of electricity and heat. Microgrids that use CHP technology have three main benefits. First, they provide electricity and thermal power from a single source of energy increasing power generation efficiency. Secondly, CHP has a type of distributed generation that decentralizes energy generation in that the generator would be close to the grid, unlike central station generation other renewables like solar could do this but not to the extent CHP does. Lastly, the ability to use the heat from energy generation to provide heat to buildings that would have otherwise been lost through generation. According to the Department of Energy, a CHP system will run at around 65-75 percent unlike the national average of 50 percent (energy.gov, n.d., 28). Having this increased efficiency when looking at the social context will show that even without renewables, a CHP microgrid can still stay in the scope of the Climate Action Plan. Using energy, especially energies that are nonrenewable, in an efficient manner will provide another example of an educational institution using alternative energy and promote CHP with renewable energies. This possible momentum of efficient energy usage will put pressure on power companies to further increase their own efficiency. UGI is one of the main power companies that provide electricity to the Pennsylvania population and to give them another example of successful CHP will only help. Installing a CHP microgrid in Lafayette could create this momentum for energy efficient microgrids and will put pressure on companies to promote more efficient uses of power and electricity. Allowing Lafayette to compete with schools doing the same thing as well as lead by example.

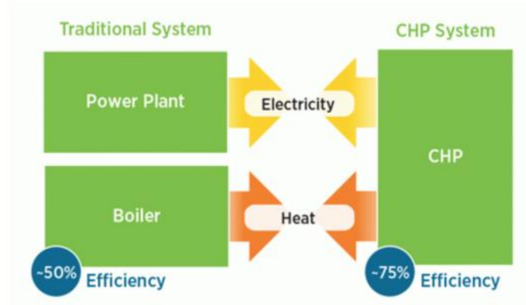

Figure 2: This is the basic format of how a Combined Heat and Power system works. The waste heat from electricity generation is used as part of the heating system

All of these microgrid options have the opportunity to give back the community in a variety of forms. An example would be providing a community center during the middle of a natural disaster. A community center will provide power to the people that are in need. Having this available to the residents of college hill and maybe even Easton could possibly improve Lafayette's reputation. An increased reputation will help with a variety of facets involving the college. A few examples could be donations, recruitment, and a more positive view on Lafayette expansion.

Political Context

Policy makers around the world have been taking note at the effects of climate change, and many have banded together in a collective effort to promote renewable energy in order to prevent further damage. In 2015, countries in the UNFCCC agreed to pursue sustainable initiatives to keep temperature increases this century under 2℃ from pre-industrial, with the ultimate goal of keeping this increase under 1.5℃ (United Nations, 2015). United States recently backed out of this agreement after the election of President Trump, however the US government still has multiple initiatives in place to require renewable energy production. Many states have renewable portfolio standards in place that lay out a plan to increase the percentage of renewable energy production out of total energy production. Pennsylvania enacted the Alternative Energy Portfolio Standards Act in 2004, which required 18% of all energy generated come from renewable sources by 2021. The program also has a seperate standard for solar PV, in which the production of solar PV energy will increase on a yearly basis. In 2017, all electric distribution companies and electric generation suppliers in Pennsylvania met the .2933% solar PV compliance percentage (Pennsylvania Public Utilities Commision, 2017). Despite the partisan differences in the views on the severity of climate change, actions are in still in place throughout the US to mitigate the risks.

Federal, state and local incentives on renewable energy make it more feasible for Lafayette to invest in renewables. At the state level, Pennsylvania has a goal to have a 30 GW solar capacity by the year 2030, which would make up about 10% of the states' energy usage

(Althoff & Altenburg, 2018). In addition to the state initiative the federal government offers tax credits that would promote solar power at Lafayette. As of 2006, the federal government has offered a tax credit of 30% for installation of solar power systems. The Investment Tax Credit (ITC) gradually starts to decrease in the next few years. In 2020, the credit will go down to 26% and further decrease to 22% in 2021 (Althoff & Altenburg, 2018). After 2021 the credit rate will remain at 10% for the foreseeable future. Lafayette will unlikely be able to take advantage of this offer as the rebate does not apply to non-profit organizations. If Lafayette is able to take advantage of this credit, they would need to purchase the solar power system in the year they plan on receiving the credit. Solar panels would also qualify for accelerated depreciation, which would further the savings for Lafayette by increasing the net present worth of the depreciation of the solar panels. By increase the net present worth of the depreciation on the solar panels, the school is lowering their taxable income, decreasing the amount they would pay in taxes. This program is planned on being phased out over the next few years unless it is renewed by Congress. Overall, if the College is not able to act soon it will likely not be able to take advantage of these federal incentives.

At the state level most of the legislation promoting solar power is geared towards residential consumers. Act 129, passed in 2008, is a major state initiative to increase the energy efficiency of appliances in Pennsylvania (KEEA, 2016). Act 129, also known as the Keystone Energy Alliance, consists of each of Pennsylvania’s seven energy companies collectively requiring themselves to reduce energy usage within the state. While this program is designed for energy companies to increase their state energy efficiency and create jobs in Pennsylvania, it may be possible for Lafayette to partner with their energy provider as part of this program to potentially help fund or operate their own renewable energy project. Pending on whether the state decides to allocate funding towards environmental initiatives, these state programs could either see their funding reduced or other renewable promotions could arise. At this point the federal legislation would be the primary driver, due to their expiring tax credit programs.

Local regulations regarding the spacing of solar panels could have a significant impact on the feasibility of some of microgrid options for Lafayette, and thus the decision-making process regarding the Climate Action Plan. In a process called net-metering, the college would be able to sell the renewable energy produced from the solar panels back to the UGI's (Lafayette's energy provider) macrogrid, and in return the college would receive billing credits based on the amount of energy sold (UGI, 2016). In order to offset the campus's energy usage, 90 acres of solar PV (photovoltaic) panels would need to be built across Metzgar. However, while Lafayette currently owns over 90 acres of land where solar panels could be installed, Pennsylvania code requires renewable energy sources to be within 2 miles of the boundaries of the customer-generator's property. Metzgar is technically not a part of the customer-generator's property, therefore it must be within two miles of campus in order to receive billing credits from net-metering. This regulation poses a problem for the implementation of a microgrid in which solar PV panels would be installed at Metzgar to power the main campus, as Metzgar is approximately 2.15 miles from that main campus (Google Earth, 2018). These regulations make it unlikely that a microgrid using solar to power the campus would be a feasible option. Another particular policy issue with constructing solar panels at Metzgar is the resulting glare from the panels that would impact the neighboring airport. The glare from the reflection of the panels could impair pilots as they try to land. A study has already been done on the fields at the Metzgar Field Complex to assess whether photovoltaic cells would distract pilot trying to land at the adjacent airport. (Fechik-Kirk & DeSalvo, 2018) The acceptable areas are show in the figure.

Any solar PV panels built on campus, such as the ones that can be built on Kirby Sports Center, must fall in line with Easton regulations. Solar PV panels must be implanted safely on rooftops. Chapter 7 of the Easton Zoning Regulations requires that materials, colors, textures, and landscaping of these panels blend into the existing infrastructure as much as reasonably possible. With low-slope roofs, such as the roof on Kirby sports center, panels must be mounted with enough setback so that the panel are not visible by individuals on the ground. Steep-slope roofs require that the panels are not visible from the street (City of Easton, n.d.). These regulations should not pose as a roadblock for the implementation of solar on campus, as the Kirby Sports Center roof layout is flat.

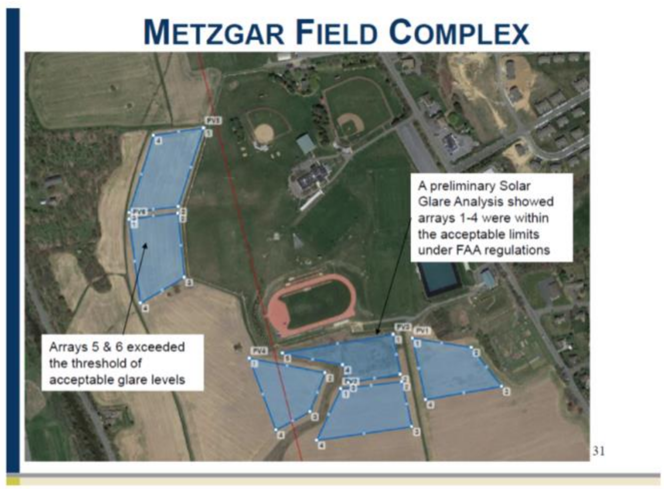

Figure 3: This map shows the Metzgar field complex and where solar panels could be installed at the facility

The use of the Metzger space will be a large topic of discussion, as the college is considering alternative uses of the large amount of space. Currently, Metzger has about 220 acres of space, with 90 acres used for athletics and 80 acres used for the adjacent farm owned by the college. Filling out 90 acres of solar would require the college to displace the local farm. Without the net-metering, commodity costs would be extremely high, making the option to power Lafayette's current campus with solar from Metzger. These estimates also do not include the colleges plans to expand in the future, such as the Rockwell Integrated Science Center and the proposed freshman housing expansion. Even more PV panels would need to be constructed to accommodate these expansion plans (Ferretti, 2018). An alternative that the Board is currently considering is to reforest the adjacent farmland in order to decrease the college's carbon footprint. This is a sensible option, as solar PV panels used to power the campus does not fit with energy regulations and expansion policies.

The Climate Action Plan and the goal of carbon neutrality itself could be quite limiting. The most feasible source of energy currently would be implementing a combined heat and power microgrid. The current steam powered generator could incorporate into a CHP microgrid, making a CHP microgrid a lot more feasible to implement. This proposed CHP microgrid using the current steam generator at the college would be sufficient to power Anderson Courtyard.

The college will have to weigh the benefits of a more feasible non-renewable microgrid, which will not help with Lafayette's Climate Action Plan, and a less feasible renewable microgrid, which could offset Lafayette's emissions. A microgrid comprised of solar energy is the more enticing option as it is completely renewable, however doubts still remain over the practicality of implementing solar. Relative to solar PV, CHP may be the less attractive option when it comes to environmental initiatives, however it will save the college a significant amount of money and energy. The tradeoff between carbon-neutrality and feasibility is going to be a key factor in the decision making process on which microgrid option to choose, and whether a microgrid should be chosen to move forward with the Climate Action Plan. There have been plans in the past to create a non-renewable microgrid solely for emergency generation. (Ferretti,

2018) While emergency generation is essential to a school with thousands of students, the school would be missing an opportunity to take control of Lafayette's emissions.

For students at Lafayette creating a microgrid could be an educational experience both in its existence and with a potential course on renewable energy. By being exposed to localized sources of energy, students will have the opportunity to gain familiarity with energy usage, the grid, and how these systems. There is often a disconnect between society and the technical aspects of energy usage, and this is seemingly because there is no need for individuals to understand these systems in order to continue with their daily lives. It is not necessary for an individual to understand the nuances of electrical engineering in order to plug in a toaster, however familiarity with the electrical principles is key to understanding how many technologies operate and how society can work towards more sustainable energy. Not only are students gaining exposure to basic energy principles, they are also gaining exposure to to renewable energy generation. Having renewable energy generation would allow students to have exposure not only to renewable energy in person but get a sense of how the larger energy system works. This potential benefit, while not specifically calculable, would increase the learning opportunities students have, particularly those in the engineering department (Hayes, 2018). Many students at Lafayette also value sustainability, as seen by the numerous student organizations that promote sustainability on campus. For example, LEAP and Eco Reps on campus promote a more sustainable Lafayette and giving these students a tangible example of renewable energy.

Having a renewable energy source at Lafayette would also make the school more appealing for prospective students. If Lafayette was to become more renewable, students would see Lafayette on the same level they see other schools with similar initiatives. A renewable microgrid would make Lafayette competitive with school like Trinity College and Dickinson College that have already established microgrids on their respective campuses (Hayes, 2018).

Another benefit Lafayette students could get from a microgrid is energy independence. In past years—such as 2012 with Hurricane Sandy and a 2016 blackout—Lafayette College has been susceptible to power outages campus wide (Ferretti, 2018). With the school becoming an increasingly global community, it is not feasible to ask all students to go home in the event of a power outage on campus. While this would not necessarily be estimable on a monetary basis, there is value to be able to provide all students with electricity and hot water independent of a larger electricity grid that is more susceptible to power outages.

Recently, Lafayette has considered implementing a microgrid in the past, however the initiative was unsuccessful. The college attempted to implement a CHP microgrid that would incorporate natural gas, thus this microgrid was focused on energy savings rather than sustainable energy sources. The proposal gained traction with the Board of Trustees, however it ultimately failed. UGI, the primary energy provider for the college, could not supply big enough pipes at a cost in which the college would still earn a significant return, as the existing infrastructure was inadequate. While the Board of Trustees has sufficient funding for the projects within the Climate Action Plan, sufficient financial return on the initial investment is necessary for any project to be implemented (Ferretti, 2018).

At various levels of policy making, emissions are being increasingly treated as a negative externality that policy is trying to reduce. The goal of policy makers in general seems to be to incentivize more renewable energy to make up for the energy market not investing in renewable resources enough to decrease greenhouse gas emissions. While Lafayette will not be directly affected by some of the policies incentivizing renewables, the momentum of renewable sources of energy provides Lafayette an opportunity to take advantage of other political actors pushing more sustainable energy. Microgrids also further decentralization, which is becoming more prominent as a whole (Resnick, 2002). By establishing a microgrid, Lafayette would become energy independent and following the lead of many political actors seeking to reduce CO2 emissions.

Technical Analysis

Description of Microgrid Technologies

"A microgrid is a localized group of interconnected loads and energy resources that normally operates connected to and synchronous with the traditional centralized grid (macrogrid), but can disconnect and function autonomously as physical and/or economic conditions dictate" (USDOE 2018). Breaking down the description of a microgrid from the United States Department of Energy there are two key technologies. First, is the ability to use energy generated from the microgrid parallel to the energy generated by the traditional electrical grid, or macrogrid in this case. Second, is that microgrids can operate autonomously from the macrogrid at any point in time. To understand these concepts we analyzed the specific technical details of three different types of microgrids. To assist Lafayette College with the Climate Action

Plan, four different microgrid alternatives have been created to help reduce carbon emissions as well as increase energy efficiency.

“Islanding” is one of the primary technologies that form a microgrid. This is especially beneficial for emergency response, and energy security. This benefit helps with one of the larger problems that centralized grids have which is the power outages that occur during natural disasters. Having a microgrid can mitigate this issue because of its ability to operate autonomously which increases resiliency and reliability. The seamless connection between the microgrid and the macrogrid which is essential to islanding also creates the opportunity to buy and sell energy from the macrogrid.

The second primary technology is the availability to sell energy created by the microgrid back to the electric company that handles the macrogrid. The traditional macrogrid is a centralized form of energy generation that focuses on mass generation from singular power plant. “electric utilities generate all the electricity they sell using just the power plants they own” (EIA 2018) Microgrid technology decentralizes energy production from the traditional macrogrid and provides the opportunity to use different distributed energy resources on a smaller scale. “decentralized solutions [microgrids] could manage the integration of thousands or tens of thousands of distributed energy resources in a way that also maximizes reliability and resilience” (Hirsch)

Analyzing the advantages and disadvantages of microgrids and traditional macrogrids offers insight on how microgrids are beneficial and complements the current macrogrid technology.. Macrogrids are centralized generators, usually power plants, that create massive amounts of energy to be distributed to the public. “In industrialized countries, microgrids must be discussed in the context of a mature “macrogrid” that features gigawatt-scale generating units, thousands or even hundreds of thousands of miles of high voltage transmission lines, minimal energy storage, and carbon-based fossil fuels as a primary energy source" (Hirsch 2018). This technology offers easy access to electricity for mass consumption. Because a macrogrid creates such a large amount of electricity for a large number of people there are two major drawbacks. One is the possibility of a blackout which is a risk to energy security. A large blackout in a major city or area can cause numerous amounts of problems, from a simple inconvenience to temporary shutdowns of businesses. The second drawback is the sizeable amount of CO2 emissions. The issues of energy security and CO2 emissions can be mitigated with the implementation of microgrids. The first mitigation aspect is the "islanding capabilities that microgrids have. This islanding capability enhances energy security especially in times of crisis and natural disasters. The second mitigation aspect is the microgrids ability to use renewable energy resources. Microgrids make it possible for institutions and residential areas be powered mostly by renewable energy. An example of this is at the University of California San Diego. The microgrid at UCSD is used to "supply 85% of campus electricity needs, 95% of its heating, and 95% of its cooling." (Berkeley Labs 2018). These advantages that come with microgrids will help distinguish itself from the traditional macrogrid. But, there are some obstacles that come with this new technology

One of the obstacles of microgrids is that they do not create massive amounts of energy unlike the traditional electrical grid. Another obstacle that is specifically for microgrids that use renewable energy generation is the variability in energy production. Solar for example, can only generate energy during the day. The way that this obstacle can be overcome is the use of energy storage. Energy generated during the day from solar PV cells can be stored for nighttime usage with proper energy storage. These obstacles can vary in magnitude depending on the type of energy generation and storage. To make sure the Lafayette is ready to implement microgrid technology we have analyzed the different types of energy generation and storage that are compatible with microgrids.

An academic journal published by Hirsch, Guerro, and Parag titled “Renewable and Sustainable Energy Reviews” provided us with a list of different types of energy generation and storage along with their respective advantages and disadvantages. The main types of generation for microgrids are microturbines, fuel cells, and renewable generation for example solar photovoltaic cells (Hirsch, 2018). Microturbines are usually small combustion turbines that have the ability to generate heat and electricity on a small scale. The advantages of microturbines are that they are dispatchable which describes the ability of a generator that can be turned on or off at the demand of the user. Microturbines also produce low emissions, have multiple fuel options, and is CHP capable. A disadvantage is that microturbines still produces some greenhouse gas emissions. Because of this if Lafayette were to use a microgrid with a microturbine the campus would not be able to become carbon neutral. To get a sense of scale in regard to emissions The U.S Department of Energy compared different types of energy generation and their respective emissions. “Emissions [for microturbines] range from 667 to 804 lbs/MWh. For comparison, a typical natural gas combined cycle power plant will have emissions of 800-900 lbs/MWh, and a coal plant will have CO2 emissions near 2,000 lbs/MWh” (USDOE 2016). Microturbines also produce energy on a relatively small scale.

Fuel cells have the ability to convert chemical energy into electrical energy that can be used in a microgrid. The advantages of fuel cells are that they are dispatchable, they have zero on site pollution, and are CHP capable. The disadvantages are that fuel cells are relatively expensive and have a limited lifetime.

The next main source of energy generation is renewable generation. The primary sources of renewable energy generation are solar photovoltaic cells, wind turbines, and hydroelectric. The general advantages of using renewable generation are that they have zero fuel cost and have zero emissions. The disadvantages are that renewable generation is not dispatchable without storage and the energy production is variable and not controllable. In regard to microgrids it is not possible to integrate these options without the ability to store the generated energy, especially for renewable energy. (Hirsch 2018).

After generation microgrids need a main storage unit to store the excess energy generated. The main types of storage units include batteries, regenerative fuel cells, and kinetic energy storage. (Hirsch 2018). The first main type of storage for microgrids are batteries which have a long history of research and development which should make it easy to implement into a microgrid but there are some disadvantages. There are two main issues that regard batteries, one is that they have a limited number of charge and discharge cycles meaning that after a certain amount of usage batteries wear out and are not as efficient. Second is the issue of waste disposal that comes with disposing the efficient batteries.

The next storage option are regenerative fuel cell which are the opposite of a fuel cell in that it stores energy instead of produces it. The unique benefit of this type of storage is that it has the ability to support continuous operation at maximum load without the risk of damage. Regenerative fuel cells are also a clean way to store the generated energy. The disadvantages are that they have a limited discharge time.

The last method discussed in this study is a flywheel a type of kinetic energy storage. A flywheel is a heavy revolving wheel that takes the energy that was generated and stored by a very high-speed rotor which keeps the energy as rotational energy (Energy Storage Association

2018). The advantages of this type of storage is that is very responsive, has a high charge-discharge cycles, and high efficiency. The disadvantages are that flywheels have high standing loses if the technology is not implemented properly (Hirsch, 2018).

The Three Types of Microgrids

There are three levels of microgrid energy production: emergency generation, demand response, and optimization (Hirsch, 2018). In an emergency generation microgrid the electrical generation is only activated in the event of a macrogrid power outage. The microgrids primary use is to support energy usage for critical facilities in the event of a natural disaster or other type of power outage. This emergency generation focused microgrid provides greater energy security and is not economical beneficial until the system becomes more complex. The next type of microgrid is one that focuses on a demand response system that would supply energy constantly. The demand response method involves either buying energy from the macrogrid or selling energy to the macrogrid. If the demand for energy exceeds its supply then the microgrid can buy power directly from the macrogrid. If the energy supply exceeds demand than the microgrid can sell energy back to the macrogrid for energy credits. If a demand response system was comprised of renewable generation, the college would decrease its currently CO_2 emissions, but would still be responsible for CO_2 from the energy supplied from UGI (Ferretti, 2018). In an optimized microgrid, the controller is highly advanced in that it analyzes the usage of energy based on cost. The microgrid controller can find the cheapest source of power to use at any given time. The price of electricity fluctuates during different times of the day due to demand. The optimized microgrid can analyze the cost of energy from the macrogrid and from the microgrid and choose which type of energy to use. If Lafayette invested in a renewable island microgrid, the school would become completely carbon neutral, and even offset some of the carbon from the city if it was to sell excess energy back to the macrogrid (Ferretti, 2018). At Lafayette it would likely be more feasible to either implement an emergency response system or a demand response system, as it would be a considerable investment for Lafayette to implement an optimized microgrid.

Four different microgrid options (Kirby/Metzgar/Anderson)

(Introduction, stating what would zero emissions look like from an energy creation standpoint, where it would go, what options the college has…)

Our group identified four alternatives to see if Lafayette can utilize a microgrid in any capacity. We focused our research on these four microgrid alternatives because they each demonstrate a different purpose or usage for the college. The first option utilizes on campus space to create power for a just some basic functions of the building the power is implemented on. The second option is another on campus microgrid that enables more microgrid characteristics, such as the option for islanding, or disconnecting from the grid while maintaining power or critical functions. The third option is an off campus option that resembles a full microgrid, being able to island as well as being able to net meter, for the off campus location alone. The last alternative is off campus as well, but instead of being able to be energy independent only from Lafayette, it would supply all of Lafayette's power needs, effectively offsetting all of Lafayette emissions.

We have decided to use the following criteria to analyze the alternatives from a technical perspective: distribution, spatial requirements, power generation options, three levels of microgrids, proximity to usage, accessibility to power or energy infrastructure, and geographical.

Energy storage was not included as a factor in order to narrow the scope of our research. Distribution refers to how the power created will be appropriated across campus. At Lafayette this includes the steam heating system used to heat buildings on campus, as well as the current electrical infrastructure. Space, or spatial requirements, refers to the actual amount of space that an alternative would require. Power generation options entails how the energy used for powering Lafayette would be obtained, whether it was solar, biofuels, or other alternative energies. The three different types of microgrids assess which degree of microgrid would be used and what level of power usage the microgrid would cover. Accessibility to power is how easily the alternative can access a specific power option. At Lafayette, this is an assessment of the ability of the school to acquire the means to generate power. For instance a combined heat and power system running on natural gas would be reliant on the school being able to attain and store natural gas. The geographical evaluates how the microgrid would be impacted by specific uncontrollable environmental or locational elements. This can be whether or not the sun is out, or how far from campus the alternative would be.

Lafayette's campus has very few optimal spaces to set up energy creation, for example, Kirby Sports Center has two and a half acres of roof space that could be turned into solar. In comparison to the total amount of solar needed to offset campus fully, two and a half acres is not enough. The campus would need the capacity for five megawatt hours (5 MWH) at any given time (Ferretti, 2018). This means that the college cannot simply have the ability to power 5 MWH but to continuously do so for *continuous operation* of critical campus processes. The equivalent of a constant 5 MWH is close to 100 acres of solar panels (Ferretti, 2018). This leaves the only option for space for a full campus microgrid powered by solar alone to be out at Metzgar Fields, where there are closer to 200 acres of accessible land. A private farmer uses 90 acres of it, Lafayette would have to let this tenant go in order to utilize the most feasible land and not disrupt the airport's activities. There is another option Lafayette can pursue which is less spatially intensive, combined heat and power. Combined heat and power (CHP) systems utilize a normal power plant, but make the excess heat created turn into a heating source for the school, increasing the overall efficiency of the process.

Kirby For Campus

This microgrid alternative utilizes solar power on the rooftop in order to power critical functions in Kirby, but cannot power the whole building. Kirby sports center has two and a half acres of accessible roof space, and is the single largest source of energy consumption on campus at close to 10% of the total consumption (Fechik-Kirk & DeSalvo, 2018). Reducing consumption by adding solar and giving it the option to island and produce energy independently would reduce the College's energy bill as well as lead the way towards further implementation on campus in the future. Although two and a half acres would not be enough to fully supply Kirby, it would allow Kirby to operate some of its critical processes such as lighting and heating in crisis situations, giving the Lafayette community as well as potentially the surrounding Easton community a shelter to use in times of crisis. Using Kirby as a potential hub for green energy would create a microgrid on the second, being able to handle emergencies mainly but also using solar would allow for a return on investment with selling the energy to the grid (Ferretti, 2018).

The Kirby microgrid alternative in terms of distribution of power would be straight forward. The power generated would be on Kirby, and can connect to the relatively new existing infrastructure. Spatially, Kirby does not offer substantial room for solar to work optimally, since it would only be powering a limited amount of Kirby processes. Solar as a power source for

Kirby is feasible with the roof space Kirby provides, and is the best rooftop on campus for solar implementation. With regards to other power generation options, solar is still the best, but in order to cover all of Kirby's power needs, another source would be needed. This other source could be a CHP plant, or biofuel generators, to remain in line with Lafayette's CAP. Using the solar would be able to maintain the first level of a microgrid, covering critical building operations such as heat or plumbing or some electrical as well as help alleviate energy costs. Proximity to usage would be in direct proximity, since the application of the microgrid and the power source are on the same building=. With the next metric, accessibility to power, there is another item to consider, whether or not Kirby is heated by steam or not, or has its own boilers. Kirby has been recently renovated and has a modern power infrastructure as well as being close to Lafayette's power station down the hill. Geographical criteria for Kirby will not impede on microgrid implementation with solar as the power source. There are no trees blocking roof coverage, so weather factors are the only worry, and the average amount of peak sunlight per day is between three and four hours.(Baker 2018)

Anderson courtyard

On campus, if the spatial factor was not sufficient, for example if the solar field did not have room and there was no way of adding room, then there are some other options like CHP, or combined heat and power. Combined heat and power has potential because of the current infrastructure in place across campus. On the hill, a central heating station boils water and turns it into steam. This steam is then sent through pipes all across campus heat campus buildings. Since there is already a current steam heating infrastructure on campus, combined heat and power may be more efficiently put to use than other alternatives like generators or even the equivalent power generation in solar (Ferretti 2018, Hayes 2018). Currently Lafayette brings in natural gas through pipes coming from a larger natural gas grid owned by UGI (Ferretti , Hayes). The change would be adding a power plant to this station to heat the water instead of just heating alone.

Multiple options for fueling a CHP plant for the microgrid fit within the guidelines of the Climate Action Plan as well, like biofuels. There is another group of Engineering Studies students researching biofuels. In the recent 2018 Lafayette Climate Action Plan over 20 alternatives for reducing emissions and reaching carbon neutrality were looked at. Microgrids as well as a biofuel power plant were amongst them. Biofuels encompass a wide range of fuel options as long as they come from renewable sources, such as vegetable oil, or wood chips or such (Wallace 2010) and Ferretti. In discussions with the director of facility operations a few that were brought up were vegetable oils and a newer biofuel called wood oil (Wallace 2010). This is what's used to turn water into steam for heating. What would be needed for a CHP system is an on-campus power plant with storage capacity as well as an energy source. Looking at these biofuels can shed light on what green/renewable energy source can be used most efficiently. Current problems with things like wood oil are its availability to Lafayette. The manufacturer of it is in Canada, so supply issues could arise in the future and that puts energy security availability into question. Storage of a sufficient amount is also an issue, the college currently has capacity for 50,000 gallons of whatever fuel would be needed, but for wood oil, with a PH of 12, there may be some changes needed (Ferretti, 2018). Using a microgrid based off of CHP would still be a very powerful and efficient option but to discuss using a CHP plant in the context of a microgrid, all of what goes into a CHP needs to be taken into account as well.

It is worth noting that when Mr. Ferretti, director of operations, made the CHP system proposal for Lafayette in the past, UGI was unable to follow through with it because of the current external infrastructure in place (Ferretti , Hayes). The pipes that supply the natural gas to the school for heating the steam heating plant were too small for the load required for a campus CHP system based off of natural gas to be feasible (Hayes, 2018). Natural gas as part of the Climate Action Plan discussion may not be a ‘green’ energy, but it does offer a reduced carbon footprint, and when used for a CHP system, does so even more by increasing the efficiency of the energy creation. Creating a CHP system for the entirety of campus would be a large undertaking, especially if it were to comply with the Climate Action Plan.

A more viable alternative is creating a localized CHP plant for Anderson Courtyard, or, to be able to power Lafayette enough to displace Anderson Courtyard’s energy usage as well as provide heat to buildings. This would allow the College to not expend excessively into one alternative, as well as allow CHP to be used on campus. Stonehouse Consulting Group is looking into viable CHP alternatives and currently there are two they are looking into (Hayes, 2018). The first is one based around steam heating using microturbines (Hayes, 2018). The second is one based around liquid heating, using reciprocating engines (Hayes, 2018). The current infrastructure in place uses steam heating, but the more efficient option is the one involving liquid, and this option also has a cheaper upfront cost associated with it (Hayes, 2018). A system like this would be able to power close to 1500 KWh, compared to campus’s total energy usage of around 6000 KWh. CHP as an alternative in the Lafayette microgrid would play a large role in contributing to distributed energy resources playing into the whole system, as well as be able to heat buildings on campus so that students stay warm even in crisis situations.

Metzgar for Campus

Another alternative that was looked at was using the ample space out at Metzgar Athletic Fields and the private farming fields as solar array space to power campus. Looking at the total power production, Lafayette would need 90 acres of solar (Ferretti, 2018). There is ample space out at Metzgar to install this much, and this would allow Lafayette to stay powered indeterminately and during peak power usage during the summer. Room is not an issue regarding where the panels could go, but the distance became an issue for net metering, as well as playing into a true microgrid (Hayes, 27). Lafayette is 2.1 miles off of campus, and UGI has a policy that no net metering can happen if the source is outside of 2 miles from the power production site (UGI, 2018). Also, in order for the microgrid to work, a direct connection needs to be established between the energy source and the campus. This makes solar power at Metzgar only able to displace what energy is used at Lafayette if Lafayette was able to net meter further than 2 miles. If Lafayette were to acquire property closer to Metzgar Fields to get into the two mile zone, then net metering would work (Ferretti, 2018). The only way this would be able to be part of a microgrid is if Lafayette installed direct lines to Metzgar fields. The implications of this could have impacts on the surrounding Easton and Forks Township community commuters in the area.

Metzgar for Metzgar

The last feasible alternative is installing a microgrid at Metzgar fields to for the Metzgar complex alone. This idea specifically power the Metzgar sports complex came from the issues that arose from the Metzgar for campus alternative. Similarly to the the Metzgar for campus microgrid, the main source of power will be from a multitude of solar arrays. The difference of this alternative is that the amount of solar PV panels needed to power the complex will be significantly lower than the previous alternative. During the periods of low energy usage at the sports complex, Lafayette College has the opportunity to sell excess energy back to UGI, the utility, with net metering. The advantage of using net metering is that Lafayette can offset their energy costs with the renewable energy sold to UGI. This alternative is the most flexible of the four because Lafayette college can decide how many solar arrays to install at metzgar to not only power the complex but to offset the campuses energy costs. While the energy used to power the campus would not be renewable if there were more arrays in this alternative, the college would still be offsetting its carbon footprint by providing renewable energy UGI.

The Metzgar for Metzgar microgrid is the most feasible alternative because of its lower upfront costs compared to, for example, Anderson Courtyard. This microgrid would fall under the second level of efficiency. It would be fully self sufficient, and be able to net meter, or use demand response. Installing a solar array out at at Metzgar would be more intensive than installing solar on Kirby's roof because it would be close to a quarter mile or more away from the facility, so there would be some infrastructure additions besides the microgrid controller. With existing power infrastructure metric, the array would connect to what is currently in place. These additions would be purely for the ability to connect solar arrays to Metzgar and to the power grid. With regards to the distribution metric, the power generated would stay at Metzgar, so it would not be distributed far or to many buildings. In addition to energy creation, energy storage would be needed as well,. Although this was not a metric that was investigated this is an important part to how Metzgar would maintain power if disconnected from the grid. Accessibility to power infrastructure would be no big deal, Metzgar is located on Sullivan Trail, which is a large road that connects Forks Township to Easton, so connecting to the power grid will not be a large project. Solar power is environmentally friendly if looking at power generation, and has little to no emissions over a typical life cycle (UCUSA 2010)

Economic Analysis

Microgrid Investment

There are multiple benefits from investing in microgrids, however financial models from investors of microgrids have yet to been established, primarily due to the complexity of capturing the value of an advanced controller that differentiates microgrids. As investors continue to understand how to monetize microgrids and develop investment models, microgrids are expected to see rapid growth in popularity. Recently, institutions have relied on government grants to partially aid in the funding for microgrids, and have used other strategies such as direct ownership, vendor financing, energy service contracts, debt financing, and bonds to fund the remainder. Those implementing microgrids have used other common energy financing models as a template for financing microgrids. Two common examples are a power purchase agreement (PPA), used by independent power generators and solar companies, and a energy savings performance contract (ESPC), a model that revolves around sharing cost savings between the contractor and the customer (Siemens, 2016).

Microgrids tend to vary in cost, depending on the scope and the type of microgrid. The main expenses that account for the total cost are the distributed generation assets, grid automation, microgrid automation software, development and installation costs, and energy storage. Much of the value from microgrids comes from the complexity of the controllers, as the complexity of these controllers increases, so does the profitability. Simple controllers keep the microgrid running constantly, and energy is purchased from the grid when there is not enough energy to meet demand. However, as the controllers become more advanced, the microgrid can optimize energy costs by switching autonomously between the grid and the microgrid based on gas and electricity prices. Microgrids are also able to produce revenue by selling ancillary services (Siemens, 2016). Ancillary services are defined by FERC (The Federal Energy Regulatory Commission) as “Those services necessary to support the transmission of electric power from seller to purchaser, given the obligations of control areas and transmitting utilities within those control areas, to maintain reliable operations of the interconnected transmission system.” (FERC, 2016). These ancillary services would include frequency control, in which the microgrid could help maintain stability in the main grid, and black start capabilities, in which the microgrid would help restore power to the main grid in the event of a blackout. Microgrids can also earn revenue by participating in grid demand response programs, where the microgrid can reduce its power dependency on the macrogrid when the macrogrid is under strain (Siemens, 2016).

Solar Estimation Method

To estimate the total cost of a solar power plant at Metzgar we used solar costs estimated per Watt (Kabir, 2018, Parkinson, 2015). These estimations break down the costs into three sections: installation, acquisition, and the PV cells themselves. Each metric had both a high and low estimate, which will give us a range of pricing options for both of our Metzgar solar alternatives. For installation costs the high cost was $0.65/W and the low cost was $0.45/W. For acquisition costs the high cost was $0.50/W and the low cost was $0.20/W. For PV cell costs the high cost was $0.50/W and the low cost was $0.40/W. This makes the total costs per Watt between $1.65 and $1.15. Additionally, these solar projects are expected to have operation costs each year. The estimations for operation costs come from the Stone House Group’s estimations for rooftop solar on Kirby Sports Center (Hayes, 2018). The annual operation costs for both

Metzgar alternatives are assumed to be proportional for to the Kirby Sports Center options. The solar panel requirements come from using the total annual energy consumption from the Office of Sustainability (Fechik-Kirk & DeSalvo, 2018). We estimate daily solar irradiation to be 4 peak hours per day (Zientara, 2018).

Metzgar for Metzgar

Implementing solar panels to power the Metzgar sports complex is likely a sound economic solution for the energy needed for the entire complex. The land that is currently being unused by the school has ample room to support solar panels that could make the complex energy independent. (Fechik-Kirk & DeSalvo, 2018, Ferretti 2018) This means that Lafayette would not have to purchase land from any nor remove the farmer currently leasing part of the land Lafayette owns around the Metzgar complex. (Ferretti, 2018) The annual energy costs of Metzgar is estimated to be the same as the average building energy cost at Lafayette (Fechik-Kirk & DeSalvo, 2018). To estimate the cost of the solar system at Metzgar we use the solar estimation method described earlier, using those source for daily solar irradiation and solar panel cost. We estimated initial costs of this system to be about $407,00 to $214,000. The annual operation costs are estimated to be $27,000 per year. Additionally, if the Metzgar facilities are not being used consistently throughout the day, which they often would be due to the practice schedules of teams, the college would be able to sell the excess energy produced by the solar system to the Macrogrid as energy credits.

Metzgar for Campus

Implementing solar panels at Metzgar to power the entire campus would be a significantly larger investment than installing solar panels just to power the Metzgar complex. This alternative would involve removing the farmer currently leasing part of the land Lafayette owns around the Metzgar complex (Fechik-Kirk & DeSalvo, 2018, Ferretti 2018). After removing the farmer, the college would lose the money that he previously paid leasing the land each year. Assuming the college is able to secure distribution back to campus from a large solar array, the school would need roughly 90 acres in order to power the entire school only on solar located at Metzgar (Ferretti, 2018). Using the assumptions from earlier in this section, the estimated initial costs of this system is between $30,514,000 and $2,267,000. The annual operation costs are estimated to be $2,000,000 per year. This large investment in solar would be risky for the school because the entire campus would be reliant on a single energy source. Therefore, if the sun did not shine enough, the school would have to go back and purchase energy from UGI, their current energy provider, and negate all the money they have invested in become carbon neutral. It would also lengthen the time that the school would require to break even from the initial capital costs.

CHP for Anderson Courtyard

A CHP microgrid for Anderson Courtyard is the most appealing option economically of all the microgrid options. CHP is extremely efficient when it comes to energy usage, as the traditional macrogrid typically only reaches efficiencies of about 30% to 40%. However, CHP is able to reach efficiencies of up to 80% to 90%, allowing the college to reduce energy costs long-term (Hirsh, 2018). The steam powered engine that the college already has would significantly reduce the upfront cost of installing a CHP microgrid. However, there are still multiple initial investments the college must make in order to implement a CHP microgrid. A combined heat and power system to power the entire campus would cost approximately $6.4 million dollars, however over a 15 year life cycle, the college would end up seeing by year 4 about $210,000 - $220,000. By year fifteen the cost of the CHP microgrid would decrease to $3.9 million dollars (Hayes, 2018). Anderson Courtyard accounts for 15% of the schools energy usage, so we would expect the present value of the cost of a CHP microgrid for Anderson to be about 590K (Fechik-Kirk & DeSalvo, 2018). This equates $66 dollars per MT of CO2 emissions saved by installing the microgrid (Hayes, 2018).

Solar Panels for Kirby

Kirby Sports Center is the building with highest energy usage on campus, thus there is plenty of potential for energy savings by powering Kirby with more renewable energy sources. The installation of solar panels is estimated to cost between $433,219 to $622,000. The expected additional operating costs over a 15-year life cycle would be $621,124, with a present value of $429,684 (Hayes, 2018). However, there is the potential for net-metering. During sunny days, especially during the summer when energy use is at its lowest, the college could sell the excess energy produced back to UGI for credits off the energy bill. Along with the microgrid capabilities and the reduction of the carbon footprint from Kirby, a solar microgrid also provides the college with long-term savings potential.

Economic Conclusion

Overall, we have concluded that each of the alternatives would save Lafayette money and contribute to the Climate Action Plan. With the two larger investments, the Anderson Courtyard

CHP and Metzgar for Campus alternatives, raise concerns due their high initial costs. It may be difficult to secure the capital to fund the projects. If both power plants were built, they would constrain Lafayette's energy to a single source of power, natural gas and solar respectively. This means the CHP alternatives effectiveness dependent on the price of natural gas or alternative fuel. Likewise the solar project would be dependent on the solar irradiation. It would be risky for the school to become dependent on one of these sources of energy. Any decrease in the school's ability to produce power would mean either switching back the macrogrid or leaving the campus without power. Even though the larger projects would pay for themselves, it is worth considering the constraints these alternatives would have on Lafayette's power generation.

The smaller projects, the Metzgar for Metzgar and Kirby Solar alternatives, would be used only to offset some of the power needs of the two buildings. This means that both solar arrays would have the ability to send unused electricity either back to the macrogrid or to other parts of campus. This means that any excess energy would either generate profit through net metering back to the macrogrid or reduce power expenses for other parts of campus. If solar irradiation is low, the buildings would still be able to plug back into the macrogrid. As a whole, the small solar projects make sense because of their lower relative cost and the complete usage of all power generated.

Solar power generation could work well for campus given the timing of high electricity usage. At Lafayette electricity usage peaks around 2:45 pm (Fechick-Kirk & DeSalvo, 2018). This means that solar panels would be producing close to or at capacity during the time that the most energy would be demanded. During these peak times electricity is also at its most expensive, maximizing the cost savings from the solar power generation. Additionally, Lafayette spends more money on air conditioning during the summer than heat during the winter. This means during the summer months, when the sun is out more, a solar power system would be generating more power to offset Lafayette’s energy usage. As a whole, a solar power system would coordinate with Lafayette’s energy needs.

The economic feasibility of these alternatives is largely dependent on the social cost of carbon used to calculate the value of the CO2 reduction achieved through the more renewable energy sources. While the projects should save the college money, factoring in the emission related externalities of Lafayette’s current energy usage, could make the microgrid options more economically viable. The higher the social cost of caron is estimated to be, the more important it will be for Lafayette to invest in renewable energy. Based on the money that could be made for the smaller projects, investing relatively small amounts in renewable energy could make economic sense if the cost of carbon is high enough.

Conclusion

In this report we did research on microgrids which can be used to not only assist Lafayette in achieving carbon neutrality, but also take steps towards energy independence. Microgrids can create renewable sources of energy for Lafayette that would decrease or eliminate GHG emissions cause by electricity use on campus. Additionally, a microgrid would make Lafayette energy independent, mitigating risk from power outages in the larger macrogrid. Furthermore, microgrids could help Lafayette stand out among other college if prospective students could see Lafayette owning and operating its own microgrid. Having a microgrid on campus would not only demonstrate Lafayette’s commitment to the environment to prospective students, but also provide a hands on educational experience to students seeking to learn more about energy generation and distribution. Microgrids open the door to solve problems like emissions reduction and energy independence, while creating an active learning opportunity for future students.

In order to assess the feasibility of microgrids at Lafayette, we identified and evaluated four possible microgrid options for Lafayette: Kirby Solar, Metzgar Solar for Campus, Metzgar Solar for Metzgar, and Anderson Courtyard CHP. Each microgrid option would have a specific goal. All four of the plans would reduce Layette's energy costs and make energy generation more efficient. The solar alternatives would help Lafayette follow the Climate Action Plan by reducing emissions, while also highlighting Lafayette's commitment to fighting climate change. The Anderson CHP alternative could help emissions reductions if it was power with biofuels. A natural gas power plant would decrease emissions in the short run, but would cap Lafayette's potential emissions reductions by constraining the power plant to a non renewable source of energy. The larger projects, the Metzgar Solar for Campus and the Anderson Courtyard CHP, would require significant capital investments and would require frequent maintenance and monitoring. The smaller solar projects, at Metzgar and Kirby, would be good first steps towards renewable energy, while saving Lafayette money on its energy bill. We recommend that the school move forward with the two smaller solar projects, since we believe they could benefit Lafayette financially and help meet the goals of the climate action plan.

The next steps for microgrids at Lafayette revolve around getting precise estimates for installation, operation costs, and their social cost of carbon. For the solar plants, several assumptions were made in order to come up with cost estimates. If Lafayette was to get more serious about installing a solar microgrid, they would have to get precise quotes on solar panels. The estimates we made are approximations, and contacting a solar company would provide accurate costs for the potential costs and benefits of solar at Lafayette. Furthermore, the social cost of carbon and the benefit from providing academic opportunities in energy production and distribution should be considered. Inserting the social cost of carbon into discussion on solar at Lafayette would make solar energy and renewable energy in general more cost effective at Lafayette. Additionally, if Lafayette knew how much future students would value living on a renewable campus as well as having the opportunity to actively participate in their school's electric system, the implicit benefits of a microgrid would become more apparent in conversations in installing a microgrid on campus. To overcome this uncertainty would require further research and deliberation on what Lafayette values and wants to see in its energy generation and distribution look moving forward.

Microgrids are part of an answer, but not a full solution to Lafayette's energy independence and emissions reduction. We only looked at four microgrid options at Lafayette, specifically ones that we felt were the most practical. This report is not a substantive list of microgrid options at Lafayette or the only steps that can be taken towards carbon neutrality. Nor is it a guide in how to install a microgrid, but microgrids can play off of Lafayette's strengths, as well as be included with new infrastructure changes. Other greenhouse gas reduction projects have been considered at Lafayette. One such plan includes planting tree at Metzgar could help Lafayette offset CO_2 emissions by providing a carbon sink (Hayes, 2018). While this plan would not change the emissions from electricity production, it could make Lafayette carbon neutral by absorbing CO_2 from the atmosphere. Microgrids can help alleviate CO_2 emissions but they are not the only way to do so. Microgrids could be implemented at Lafayette in conjunction with other carbon offsetting projects to help reduce the impact of Lafayette on the environment.

After holistically evaluating microgrids, we feel that there are various potential benefits of microgrids at Lafayette. Further research is necessary before investing in microgrids at

Lafayette, but our preliminary report identifies potential microgrid options to be considered moving forward. By researching a few of the possible microgrids options, we hope to provide a benchmark for future inquiries into microgrids, and outline the alternatives we feel could work at Lafayette.

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