Team Solar FYS

Fall 2021 EGRS Senior Capstone Project

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Abstract

Despite clean energy alternatives, the United States of America still heavily depends on the use of fossil fuels. Solar energy is a promising energy source that is both an environmentally friendly and sustainable solution. Scholars argue that, for the United States to transition to more solar energy, U.S. citizens must be exposed to more solar energy education. More so, scholars argue that this type of education is valuable at any age group, particularly age groups of early elementary. This capstone project explores solar energy education within the context of Lafayette College through the proposal of a first-year seminar course that extends solar energy education to age groups outside of higher education. (Yogi Goswami, 2001)

Introduction

Colleges and universities maintain the responsibility to educate and equip rising generations to evaluate and seek sustainable solutions to the world's most inequitable and critical circumstances. Climate change is at the forefront of society's most prominent and pressing issues. Both experts and common people debate the route best taken. Much of this debate is rooted in both the private and public sector's limited capacity to allocate resources towards initiatives and policies that mitigate the adverse effects of climate change. At the undergraduate level, practicing sustainability, pursuing renewable energy, and educating students on climate change are actions that higher education institutions can take to prepare students to be leaders and problem solvers in the realm of climate change. (Gernaat et al., 2021)

Lafayette College offers a unique interdisciplinary major, Engineering Studies (EGRS). Engineering Studies requires students to connect the socio and technical aspects of engineering with the goal that students become future leaders who can analyze, understand, and connect the different dimensions of engineering. With climate change being an issue that is deeply interconnected with political, economic, technical, and social facets, engineering studies students at Lafayette are well equipped to create sustainable and successful solutions for climate change. Additionally, a multitude of clubs and organizations on campus with a focus on sustainability are available to students. Particularly, Lafayette has recently invested in the creation of an office dedicated to sustainability. The Lafayette Office of Sustainability communicates a clear list of goals and motives for the college, as articulated through Lafayette's Climate Action Plan (CAP). (Lafayette College Office of Sustainability, n.d.) (Lafayette College Engineering

Studies Division, n.d.)

In the past year, in addition to these actions, Lafayette constructed a solar array atop the roof of the Kirby Sports Center located on campus. On top of the clean energy it produces, the array serves as a physical representation of Lafayette's commitment to sustainability and recognition of the importance of climate change problem solving. The Kirby Solar Array offers an opportunity for a comprehensive facility that extends beyond transferring solar energy into electrical energy. **This capstone project is a formal proposal for the implementation of a first-year seminar (FYS) under the Engineering Studies division at Lafayette College that utilizes the Kirby Solar Array to introduce the unique socio-technical major while also fulfilling Lafayette's institutional responsibility to educate future generations to be informed citizens and influential leaders who are capable of working towards sustainable solutions.**

The Problem Overview

What Problem is Team FYS Trying to Solve?

Lafayette College has invested in a newly constructed solar array located on top of the Kirby Sports Center. As of now, the Kirby Solar Array only serves to generate energy for the gym. Team Solar FYS worked to solve the following question to extend the functionality of the array: *How can Lafayette College shape the Kirby Solar Array into an engaging educational and community driven facility?* (Lafayette College, 2021)

Figure 1: "The Kirby Solar Array" (Lafayette College, 2021)

Solar Technology

Solar energy usage can be traced back as far as 7th century B.C. when humans used sunlight to start fires using magnifying glass materials. This early tinkering was the foundation that led to the development of solar panels. While difficult to credit a singular inventor for the solar panel, the most widely credited are Daryl Chapin, Calvin Fuller, and Gerald Pearson's creation of the silicon photovoltaic (PV) cell at Bell Labs in 1954. Many argue that this event marks the true invention of PV technology because it was the first instance of a solar technology that could power an electric device for several hours of a day at four percent efficiency, a mere fraction of modern-day panels. (Richardson, L, 2018)

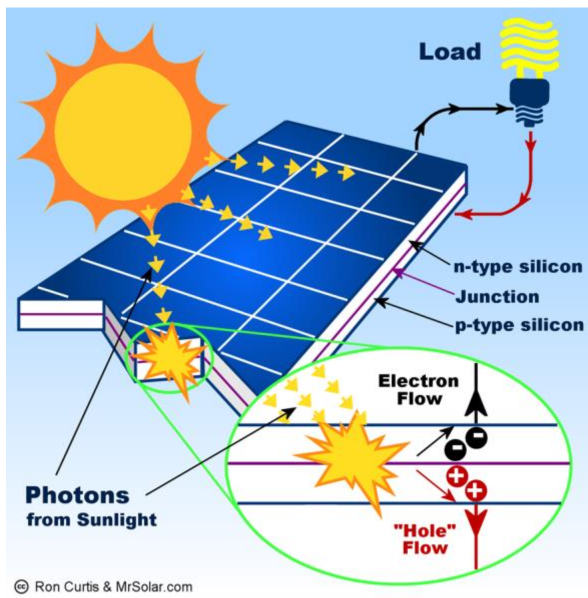

Figure 2: "Dissecting Photovoltaic Technology", (Online Solar, LLC, 2021)

Today, two main categories of technology are used in solar energy production. The first technology is concentrating solar-thermal power. The second technology is photovoltaics, which is generally used more widely, and what is used in the solar array on Lafayette's campus. The PV cells within the array absorb the energy from the electromagnetic radiation that shines onto the panel from the sun's rays. A semiconductor absorbs the radiation and transfers the energy to electrons before the PV cell ultimately absorbs the converted electrical current. Due to its relative expense, silicon is the most common semiconductor among industry PV cells today. There are also several different factors that contribute to a solar panel's capacity to convert sunlight into electricity including shade, heat, dirt, temperature, and reflection. Because solar panels only have the capacity to store so much energy, and the sun only shines for so many hours in a day, battery storage plays an important role in the efficiency of PV panels. In fact, historically high costing battery storage have limited the expansion of solar and other renewable energies. In recent years, however, the cost for battery storage has rapidly declined. The U.S Energy Information Administration states that "the average energy capacity cost of utility-scale battery storage in the United States has rapidly decreased from $2,152 per kilowatt hour (kWh) in 2015 to $625/kWh in 2018." With the reduction in battery storage costs, solar has become more affordable and feasible than in the past. (Hoff & Mey, 2020)

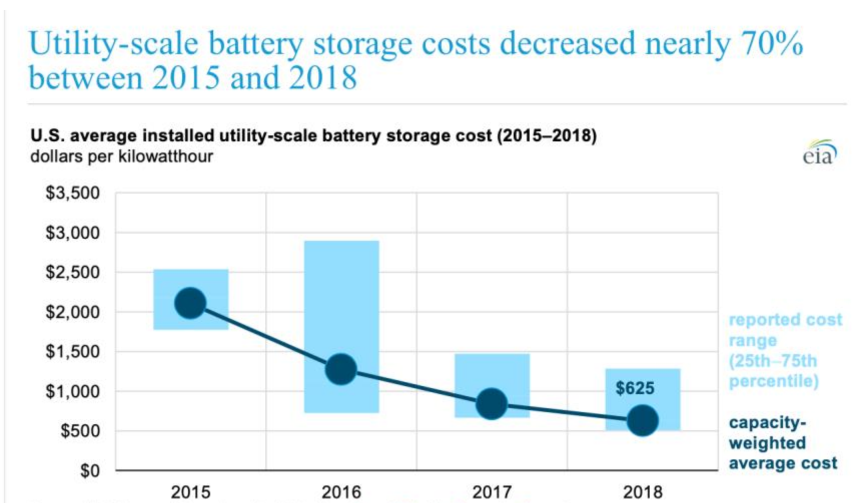

Figure 3: "Solar Battery Cost Reduction from 2015-2018", (Hoff & Mey, 2020)

Momentum Behind Sustainability

Policy is a predominant dimension that provides rationalization for the construction for the Kirby Solar Array. Environmental and sustainable policy is deeply rooted in the complexity of factors that exploit Earth's resources, deteriorating the world's environmental health. According to Harvard Business School, the tragedy of the commons is an economic theory that states, "individuals with access to a shared resource (also called a common) act in their own interest and, in doing so, ultimately deplete the resource" (Spiliakos, 2019). These actions can result in overfishing, the ruining of forests and ecosystems, and overhunting of species. In addition to depletion, the tragedy of the commons can be applied to pollution, putting in chemicals, heat, radioactivity, waste, etc. into the environment. While engineers are often eager to implement a technological fix, climate change cannot be simply resolved through the implementation of more technology, which often contributes to the pollution we observe. Garret Hardon states "the pollution problem has no technical solution; it requires a fundamental extension in morality." Even so, a "fundamental extension in morality" is a nearly impossible solution for a problem that requires immediate action. For this very reason, policy makers work to create strategies that start to address the extensive and elaborate problem, holding individuals and corporations accountable. Policy is a tool that leaders use to integrate technology and society to undertake potential solutions which address the Tragedy of the Commons and lack of accountability for Earth's precious resources. Historical policies relating to environmental sustainability are greatly influential to Lafayette's journey towards institutional sustainability. (Hardin, 1968, 1243-1245)

On a global scale, there are current and historical policies that attempt to address the issue of sustainability and climate change. It is a topic that has become widely politicized, yet one where societal collaboration is vital. Responsibility for reducing harmful toxins to our climate, increasing our use of renewable energy, and educating younger generations stretch from our individual communities and lifestyle to the leadership of entire nations and political leaders. In a global sense, collaboration towards addressing climate change can be seen through the Paris Climate Agreement. Taking place in 2016, the Paris Climate Agreement was signed by a multitude of participating nations with the goal of reducing global warming to below two degrees Celsius relative to the temperatures before the industrial revolution. Renewable energy sources, specifically wind and solar, play a major role in the quest to mitigate global warming to below the two-degree Celsius threshold. The agreement not only represents the need for worldwide collaboration towards reducing global warming, but also the desire and necessity to make meaningful changes now. The ever-increasing effects of climate change urgency provide necessary context for why sustainable solutions and policy have quickly become important for the Earth's future.

Momentum towards clean and renewable energy is also at the national level, most recently, through President Biden's infrastructure plan. President Biden's $2.3 trillion infrastructure plan explicitly states the goal of producing all energy 100% emission free by 2035. In addition to increased use in wind and solar energy, the plan would also retool U.S. manufacturing to build zero emission transportation infrastructure like zero emission vehicle fueling and charging stations. The plan proposes initiatives in a variety of different areas, but those tackling climate change have quite a high priority and monetary designation. (Trabish, H. K).

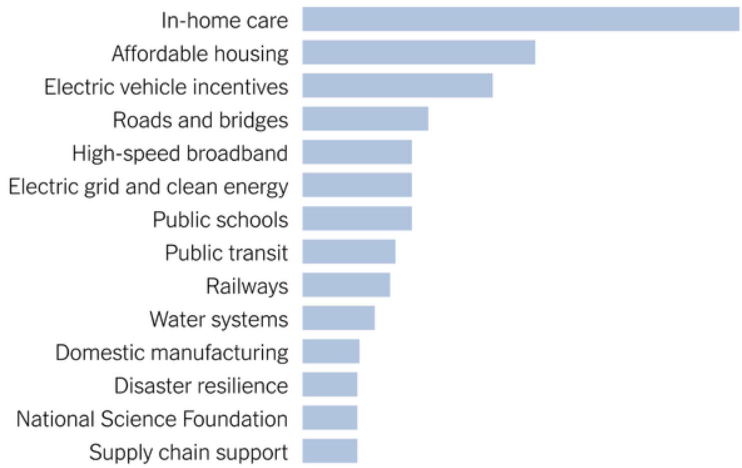

Figure 4: “Monetary Breakdown of President Biden’s Infrastructure Plan”, (Tankersley, 2021)

Electric vehicle incentives and electric grid and clean energy are both among the higher designations among Biden’s plans. As The New York Times writes, “Mr. Biden’s pledge to tackle climate change is embedded throughout the plan. Roads, bridges, and airports would be made more resilient to the effects of more extreme storms, floods and fires wrought by a warming planet. Spending on research and development could help spur breakthroughs in cutting-edge clean technology, while plans to retrofit and weatherize millions of buildings would make them more energy efficient.” While supporters of different political parties may debate over the economics behind the plan, there is general agreement over the necessity for sustainable solutions poised to protect society from the irreversible damage associated with climate change. (Tankersley, J, n.d.)

Sustainability and Education

Actions from colleges and universities around the country also mirror the political movement towards a more sustainable future. Lafayette works in collaboration with the Association for the Advancement of Sustainability in Higher Education (AASHE), an interest group dedicated to bringing sustainability efforts to college campuses and universities around the country. AASHE was officially founded in December of 2005, serving as the first professional higher education association for the campus sustainability community in North America. On their website, AASHE states a clear and concise mission statement: “To inspire and catalyze higher education to lead the global sustainability transformation.” Evidently, AASHE views higher education programs as potential leaders and catalysts for greater sustainability transformation. Moreover, their visions involve establishing sustainability efforts on college campuses to be a foundation for a thriving, equitable and ecologically healthy world. (Association for the Advancement of Sustainability in Higher Education, n,d,)

AASHE outlines four distinct strategic goals to achieve their aspirations. Their first of these goals is to “empower members to be transformational leaders for sustainability by providing indispensable resources and outstanding professional development.” To achieve this goal, they lay out the following plan:

- Develop new and improve existing resources, tools and publications
- Strengthen the annual conference and expo to be the marquee forum for all stakeholders within the higher education sustainability community
- Offer high-value professional development programs
- Expand opportunities for networking and building community

Their second goal is to “catalyze sustainability action and innovation through STARS.” AASHE created STARS (Sustainability Tracking, Assessment, and Reporting System) as a method of monitoring and improving sustainability efforts on college campuses. The STARS system measures sustainability metrics through several different sectors, including academics, engagement, operations, planning & administration, and innovation & leadership. Within each sector, there are several different areas, each with criteria that makes up a grander score. For example, within the operations sector, there are nine different areas: air & climate, buildings, energy, food & dining, grounds, purchasing, transportation, waste, and water. Then within just the air & climate sub-sector, there are scores related to a college or university’s emissions inventory and disclosure, as well as their greenhouse gas emissions. STARS is quite a powerful tool and to achieve their second goal, they outline the following plan related to the use of STARS:

- Simplify reporting requirements and reduce barriers to participation in STARS
- Strengthen the value of a STARS rating
- Improve the quality of STARS data
- Increase net income for STARS

The third goal AASHE lists to achieve their larger aspirations is to “accelerate higher education’s contributions to global sustainability through increased outreach, communications and advocacy.” This goal is probably the most conceptual among the first three, in the sense that there are no clear-cut steps towards achieving it. Regardless, it reflects the desire to implement policies and support for sustainability among higher education institutions, and the belief that said institutions have the potential to be quite impactful in nationwide sustainability efforts. Their plan for this goal is as follows:

- Advocate for policies that advance sustainability in higher education
- Champion the value of sustainability in higher education and increase support for sustainability in academics, engagement, operations and administration
- Identify new, high impact strategies to best advance our mission

Lastly, AASHE hopes to "enhance organizational capacity & resilience." This goal is centered around internal improvement among AASHE. The plan to achieve their goal is as follows:

- Grow the AASHE member community
- Optimize internal efficiency and improve customer experience
- Strengthen organization leadership and governance
- Create a culture that supports employee well-being and motivation
- Ensure AASHE's financial health and stability

The goals and ambitions of AASHE provide context towards the importance of sustainability movements on higher education institutions across the country. Using the STARS system, AASHE can monitor and track several areas in which sustainability efforts can be implemented into college campuses. AASHE and their corresponding STARS system illustrate the many different areas within a college campus that can involve aspects of sustainability. (Association for the Advancement of Sustainability in Higher Education, n,d,)

Sustainability at Lafayette College

While AASHE is a public interest group, there are many different influences that help shape Lafayette College's path towards a more sustainable future. Political, moral, ethical, and market failures are all incentives to implement public policy. Ethically, many U.S. citizens recognize the need for more environmentally sustainable solutions. Economically, solar panels are becoming increasingly more affordable. Political pressures, both from informal policy actors and interest groups, and technological advancements help to shape the current policies. Similar to policy makers in the United States, Lafayette College experiences pressures to implement policy and change on an institutional level. In response to the political pressures of being a state-of-the-art college concerned with sustainability, Lafayette crafted the Climate Action Plan, which articulates the future goals and initiatives related to sustainability at Lafayette. The Kirby Solar Array is the next step in Lafayette College’s quest to achieve their overarching goals outlined in the Climate Action Plan.

Lafayette College’s Climate Action Plan

Lafayette’s Climate Action Plan starts with a clear vision: to achieve carbon neutrality by or before 2035. Going a step further, the plan reiterates its fundamental belief in the importance of mitigating climate change, the role the college has in preparing students to be active leaders in this movement, and the hope to use campus as a living laboratory. The plan states, “By providing students with rigorous academic preparation and research training within an interdisciplinary, collaborative environment, our faculty are already preparing the next generation of scientists, engineers, architects, and policymakers to make meaningful contributions to society. Making carbon neutrality and sustainability more broadly strategic focal points of that preparation is only appropriate, as climate change is an urgent, complex, and persistent challenge. Through leadership opportunities, volunteer efforts, course collaborations, and a host of environmental research efforts led by faculty members, students will leave Lafayette understanding their ability to help shape an environmentally sustainable future."

On top of the educational components Lafayette students will receive in the quest for carbon neutrality, Lafayette also believes this movement will have a positive impact on student recruitment, the Easton community, and will work to unify the campus. The plan states, "…reaching carbon neutrality should increase organizational efficiency, reduce risk, and help to attract, retain, and motivate students and employees… Additionally, strong sustainability practices help to recruit highly skilled and motivated faculty and staff who are eager to work for organizations making a positive impact on the world. Research, education, and outreach for reducing greenhouse gas (GHG) emissions helps to strengthen community relations, enhance partnerships, and unify the campus around a shared sense of purpose." The support and push for sustainability efforts on Lafayette's campus have certainly become an important vision of the school's larger goals and educational tools for its students. In just a few years since the first Climate Action Plan at Lafayette was drafted, Lafayette has reduced carbon emissions, declared sustainability as one of Lafayette's three core institutional values, signed the "We're Still in Pledge" in support of climate action to meet the goals of the Paris Climate Agreement, and created degree programs in Environmental Studies and Environmental Science. (Lafayette College Office of Sustainability, 2021)

The Kirby Solar Array

The motives behind the installation of The Kirby Solar Array echo the values and missions outlined in the Climate Action Plan. The Kirby Solar Array project was headed by Delicia Nahman, the director of the Office of Sustainability at Lafayette. On the motives behind the array's construction she says, "This project is intended to visually articulate to the Lafayette community and visitors the College's commitment to achieve carbon neutrality and use the campus as a living laboratory." Lafayette recognizes the influence they have as a higher education institution to both contribute to solving global climate change as well as educating its students on the importance of sustainability.

Proposed Solution

For the Kirby Solar Array to truly manifest its intended potential, an educational component is indispensable. The Kirby solar array can act as not only a physical representation of the college's commitments towards sustainability, but also as a hands-on educational tool for students and even the Easton community. Without the space on campus to construct an on-site solar array with capabilities to power most of Lafayette's campus, the Kirby array will be most influential through its integration into the curriculum. The curricular integration portion of the Climate Action Plan states that "embracing the opportunities presented by transforming our campus into a living laboratory will enhance the learning environment and deepen the educational experience Lafayette provides." Team Solar FYS proposes a first-year seminar as an optimal avenue for the Kirby Solar array to develop into a facility that reaches sustainability initiatives and values both inside and outside of the classroom. Through the addition of this proposed course, use of the Kirby Solar Array can extend beyond clean energy production and its being as a physical representation of Lafayette's sustainability goals. (Lafayette College Climate Action Plan, 2020)

The figure below dissects Lafayette College's Climate Action Plan to show how its missions are multifaceted and interconnected. The right side of the diagram shows the CAP components that reach beyond Lafayette curriculum while the left side of the diagram shows how the CAP influences the college inside the classroom and on an individual experiential basis.

Figure 5: "Breakdown of the CAP Components" (As created by Team FYS Solar, 2021)

About the FYS

Inspiration From Other Institutions

We call upon other higher education institutions that not only have solar arrays on their campus, but also integrate them into their curriculum to help design and structure our FYS course. North Carolina State University (NCSU) is a notable higher education institution that a peer capstone group (Team Lafayette Clean Energy Center) references in their work. Not only does NCSU have a vast solar array located on their campus, but they also have an entire center dedicated to clean energy. The N.C. Clean Energy Technology Center was founded in 1987, initially as the North Carolina Solar Center. As written on their about us page, "the Center provides services to the businesses and citizens of North Carolina and beyond relating to the development and adoption of clean energy technologies. Through its programs and activities, we envision and seek to promote the development and use of clean energy in ways that stimulate a sustainable economy while reducing dependence on foreign sources of energy and mitigating the environmental impacts of fossil fuel use." By reviewing how the Clean Energy Technology Center and NCSU's solar array are integrated into their curriculum, we can gain valuable insight into how we envision the structure of our FYS. (North Carolina State University, n.d.)

NCSU offers two majors related to sustainability, Environmental Technology (ET) and Sustainable Materials and Technology (SMT). The structure of these majors aids in the creation of our proposed FYS. Both programs follow similar patterns in their curriculum. They start with courses on the fundamentals of renewable energy technologies, including biomass and biofuels, geothermal systems, solar thermal systems, photovoltaics, wind energy, and hydroelectric. After the fundamentals, higher level courses are offered relating specifically to solar energy that ground these earlier concepts with real-life data and applications to the array on NCSU's campus and clean energy center. While we design an FYS course rather than structure an entire major, our course syllabus echoes a similar design as the ET and SMT majors offered at NCSU in that it will start with broad concepts related to solar energy and later ground these ideas using the Kirby array. In addition, like NCSU, we hold class in the Lafayette Clean Energy Center (a new center proposed by our peer capstone group) to fully immerse students into the technical aspects of solar energy. (North Carolina State University, n.d.)

Introduction to *Solar! An Array of Energy and Education*

Team Solar FYS proposes the creation of an FYS under the Engineering Studies department titled *Solar! An Array of Energy and Education.* The course starts with the basics on the different types of renewable energy and their relative feasibility, the facts behind climate change, sustainability at Lafayette, and the current progress and path the U.S. is on in terms of their energy production and renewable initiatives through an economic, social, and political lens. After foundational lessons, the course grounds concepts to Lafayette specifically, using statistics and sustainability goals related to Lafayette, as well as calculations with data that comes directly from the Kirby Solar Array. The end of the course consists of collaboration with Easton Public Schools as a way for the FYS students to both demonstrate and reflect on the knowledge they have learned, as well as extend this knowledge to a younger generation of students.

The first-year seminar takes place in the Clean Energy Center, a proposed facility from a peer EGRS capstone group that utilizes the array to facilitate clean energy education to the college and greater Easton community. Part of the proposed Clean Energy Center is the installation of a smart microgrid and renewable technology research laboratory (SMRT). The inspiration for this lab came from Lehigh University. The equipment in Lehigh's SMRT lab includes a modular multi-level converter and a renewable microgrid and shipboard power system testbed. Team Clean Energy Center states that "students can use similar technologies to those used at the SMRT lab to analyze the energy output of the solar array." In the FYS, students will extrapolate data using the SMRT lab at the Clean Energy Center throughout the semester. (Lehigh University, 2020) (Team Clean Energy Center, 2021)

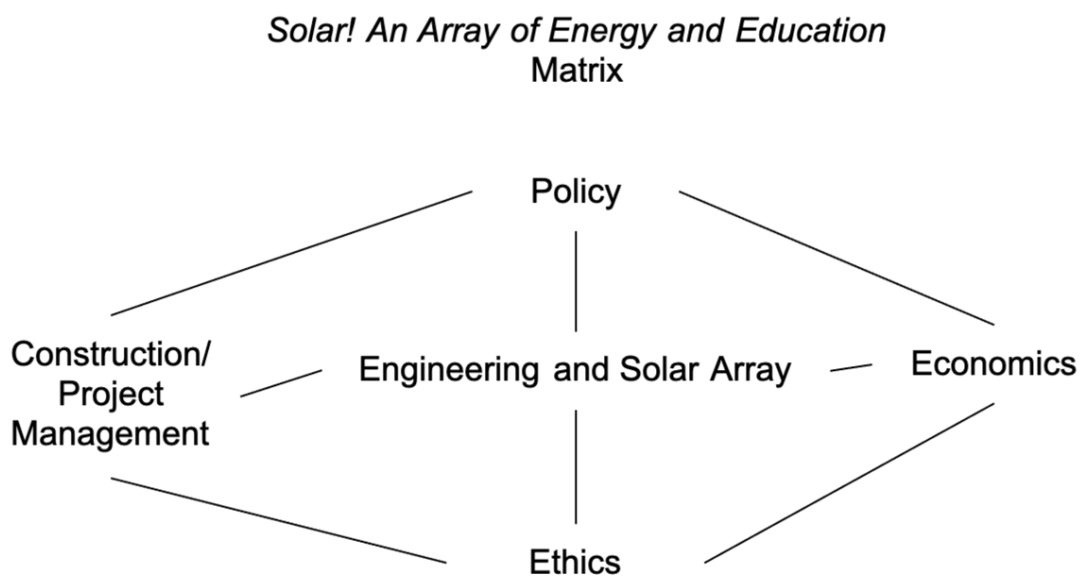

Figure 6: "Solar FYS Component Matrix" (Team Solar FYS, 2021)

Course Content

Weeks 1-10

The first ten weeks are utilized for sustainability curriculum through the examination of the Kirby Solar Array. The data extrapolated from the SMRT is used for problem-based learning to facilitate the different EGRS lenses. Throughout the semester, students gain exposure to the EGRS curriculum and methodology. First year seminar students gain a surface level understanding of the fundamental EGRS course learning outcomes. The fundamental EGRS courses include *Introduction to Engineering and Public Policy* (EGRS 251), *Engineering Economics and Management* (EGRS 261), and *Seminar on Engineering and Society* (EGRS 451) in addition to the other technical engineering courses that Engineering Studies majors take.

The technical elements of the FYS heavily engage meaningful data extrapolated from the SMRT lab and the use of photovoltaic systems technology in order to facilitate project-based learning. The photovoltaic portion of the FYS takes inspiration from North Carolina State University's (NCSU) *ET 220: Solar Photovoltaics Assessment.* As it states in NCSU's course catalog, "this course introduces specific elements in photovoltaic (PV) systems technologies including efficiency, modules, inverters, charge controllers, batteries, and system installation. Topics include National Electric Code (NEC), electrical specifications, photovoltaic system components, array design and power integration requirements that combine to form a unified structure. Upon completion, students should be able to demonstrate an understanding of various photovoltaic designs and proper installation of NEC compliant solar electric power systems." While our FYS is not heavy on the technical aspects of PV systems, topics such as photovoltaic system components and array design are certainly areas that are covered in FYS course. (North Carolina State University, n.d.)

Similar to the technical engineering elements of the course, the economic engineering elements also extrapolate information from the SMRT lab as a means to facilitate economic modeling through meaningful data. The economics lessons taught in the class are based on the information taught in EGRS 261. From the Lafayette course catalog, EGRS 261 "addresses the concepts and analytical techniques of engineering economics and management. Topics include present and annual worth analysis, rate of return analysis, benefit/cost analysis, capital budgeting, scheduling, optimization, and decision-making under uncertainty." Although the lessons taught in our FYS are more surface level than 261, they still provide a base level of engineering economics that are used later in the major. An example of an assignment that is given during this section of the course is using the Kirby Solar Array to calculate present and future worth of the solar array and calculating the payback period of when the array will break even and begin profiting from its initial cost. (Lafayette College, 2021)

The political elements of the course utilize the Kirby Solar Array for students to understand the interactions between technology and politics. Politics and technology are explored in-depth during EGRS 251, *Introduction to Engineering and Public Policy,* a class that engineering studies majors take in their sophomore or junior year. From the Lafayette course catalog, EGRS 251 "introduces students to the governance of science and engineering. Course topics include the overall context for science and engineering policy, the public policy process and institutions involved in that process, and several current science and engineering public policy issues." During weeks 1-10, the first-year students are taught lessons that pull from EGRS 251 and give a base level understanding of policy crafting and implementation in engineering projects. An example of an assignment that is taught in this section of the course is reading and synthesizing Lafayette's climate action plan, so the students are well versed on Lafayette's sustainability goals. They then produce a two-page report on what they understood in the plan and what can be improved. Students will also explore local Easton policies that influence and affect solar energy. (Lafayette College, 2021)

Social elements of the FYS involve all other elements and introduce students to engineering through an interdisciplinary lens. From the Lafayette course catalog, EGRS 451 "focuses on how engineering impacts society as well as how society impacts the practice of engineering. Students apply the knowledge they have gained from both engineering and non-engineering courses to evaluate these impacts." A fundamental and continuous discussion in EGRS 451 is how technology is human driven. For this reason, it is important for students to understand how influential society is with technology. In the FYS, this lesson is taught towards the end of the first ten weeks, so that the students can apply this community centered lens to examples of engineering projects that will make them multi-dimensional engineers. An example of a lesson that is taught in this section of the class is reading a case study from *Engineering and Sustainable Community Development* where engineers do take community needs into account when crafting solutions. The students then write a three-page paper exploring the different social facets that interact with both the Kirby Solar Array and solar energy beyond Lafayette College.

(Lafayette College, 2021)

<u>Weeks 11-15</u>

Preparation for the Easton Public School students happens during week eleven, before their visits to Lafayette College during weeks twelve through fourteen. Leading up to week eleven, FYS students are placed in lesson groups of four to five. Each group is assigned a teacher and class year from the Easton Public School District in addition to the date that the class of school children will visit Lafayette. Because each school class only visits Lafayette once, each group of first year students only need to facilitate their prepared lesson plan once. During week eleven, students work with guest lecturers Delicia Nahman and Professor Novella to utilize the knowledge they have gained throughout the semester to create a single lesson plan to facilitate renewable energy education for the children. See below for a more detailed explanation on the utilization of Delicia Nahman and Professor Novella during week eleven. The students are expected during week eleven to set up a time to meet with the Easton school teacher to practice lesson facilitation and receive feedback, ensuring that the lesson plan is appropriate for the respective grade/age group.

When the Easton students come to visit during weeks twelve through fourteen, the facilitation of the lessons happen in the Lafayette Clean Energy Center. Although seeing the Kirby Solar Array up close is a valuable endeavor, bringing an entire class of school children to the roof is unsafe and distracting, particularly with cars driving by and sports practices. More so, because weeks twelve through fourteen occur late in the semester, there is the potential for ice, snow, wind, or rain. With first year seminars at Lafayette

College averaging around twelve students, each lesson group consists of around four first year students per one Easton school class. The classes visit the Clean Energy Center on Thursdays of weeks twelve through fourteen while Tuesdays are reserved for the first-year seminar to prepare for the visits, collect solar array information, and have discussions on supplemental materials.

Week fifteen is the conclusion of the semester. During classes in week fifteen, students reflect and discuss their experiences both learning and facilitating solar array education. Outside of class, students write a five-page reflection on their experiences while also tying in the greater importance of solar energy education on a national level, utilizing a socio-technical lens. The goal of this final assignment is for students to demonstrate their understanding of socio-technical projects and the EGRS methodology, while synthesizing the information learned throughout the course.

See appendix for a daily breakdown of the course syllabus and structure

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Who Will Teach the Course?

In an audit of potential professors to teach the proposed FYS, there are numerous suitable professors. Ideally, the course is taught by an EGRS professor, one who understands the nature of Engineering Studies and can properly expose Lafayette's newest class of students to its unique curricular goals as well as holistic and perspective lens in which engineering studies students view engineering projects. Also, our FYS professor is one who has a background on solar and renewable energy.

With these goals in mind, Professor Nicodemus of the EGRS department quickly became the top choice to teach our FYS. Professor Nicodemus has taught a number of courses within the Engineering Studies department related to climate change, sustainability, and renewable energy. One course related to these subjects that Professor Nicodemus has recently taught is *EGRS 352: Energy Technology and the Modern World*. This course delves into how the U.S. currently creates and stores its energy, the impacts these processes have on our climate, and how and why these processes may change in the future. As Professor Nicodemus writes on the course syllabus, “we will examine the social, political, and environmental contexts and consequences of resource extraction, energy generation, and end use. These contexts and consequences include global climate change, environmental pollutants, economic development, inequalities in access to energy and exposure to harm, the energy-water nexus, politics, and current and potential energy and environmental policies.” The goals and lessons instructed in this course are echoed in a lower level EGRS course also taught by Professor Nicodemus, *EGRS 152: Power! Energy Technologies in Context.* As it states in Lafayette’s course catalog, “in this course, we investigate fossil fuel based, nuclear, and renewable options for producing energy in the transportation, electrical, and buildings energy sectors. We will examine the social, political, and environmental contexts and consequences for our energy use, including global climate change, environmental pollutants, economic development, and inequalities in access to energy and exposure to harm.” *EGRS 352* and *EGRS 152* share much of the same learning goals and topics. Both examine the social, political, and environmental contexts and consequences of energy use while exploring the potential of renewable energies. Through our FYS centered around the Kirby Solar Array, we hope to educate Lafayette's freshmen on, not only solar and renewable energy, but also expose them to the methodology in which Engineering Studies students explore and discuss technology. As seen by the syllabi of previous courses, Professor Nicodemus is a highly qualified candidate to teach the proposed FYS. (Lafayette College, 2021)

Due to the limited faculty working within the Engineering Studies department at Lafayette College, scouting an appropriate professor for the FYS is demanding. While a professor from the Environmental Studies division at Lafayette could be recruited, it is unlikely they will be able to translate solar energy through a socio-technical lens. Thus, this option weakens the EGRS introductory nature of the course. More so, while an EGRS professor is ideal, coordinating a professor in the division who is available could be difficult. Thus, it is the hope that the implementation of this FYS through the allocation of an appropriate professor would be an investment for the EGRS division. By allocating someone like Professor Nicodemus for an FYS, the EGRS department would have more real-estate to expose Lafayette students to the major, increasing the opportunity for more students and faculty. In the case that Professor Nicodemus does not teach the FYS, the FYS content and material can be catered to the respective EGRS professor. For instance, because Professor Sanford's teaching interests include Urban Planning, the FYS could be reframed to incorporate material that focuses on solar arrays in urban environments (*Kristen L. Sanford · Engineering Studies · Lafayette College*, n.d.). In any case, an appropriate professor will both have a background in sustainability and socio-technical skills.

The course syllabus also mentions guest lectures by Professor Novello and Delicia Nahman. Professor Novello teaches *EDUC 150: Fundamentals of Education* here at Lafayette. While that course touches on some of the historical, political, and legal aspects of teaching, it also incorporates lessons on the philosophical perspectives and methods to effective instruction. During week eleven's guest lecture, Professor Novello shares her expertise to help prep the Lafayette students to be as influential as possible when collaborating with Easton students. Delicia Nahman also brings a unique perspective to the FYS course. As the head of the Office of Sustainability at Lafayette, there is arguably no other individual on Lafayette's campus that has the understanding and knowledge of Lafayette's current sustainability practices, future goals, and endeavors.

Costs

Unlike other institutions, Lafayette does not charge students a fee on a class-by-class basis. Thus, the payment for this course is covered by the overall figure of Lafayette's semester tuition rate. The second economic cost is transportation for the Easton Public School students. The school kids are not charged for transportation. The transportation fee is covered by a donor program. The donor program allows Lafayette alumni, students, trustees, friends, and/or family to provide the necessary transportation funds to get to campus. This donor program makes the field trip to the Lafayette Clean Energy Center as accessible to all Easton students, denying no students for their inability to pay. The final economic cost is the operation and maintenance of the physical array. These costs are also covered by Lafayette. However, there is the potential for Lafayette College to employ senior and junior engineering students to work on the array, performing the maintenance and ensuring smooth operation. This opportunity gives upper-level students a chance to gain hands-on experience with the array.

Collaboration with Easton Public Schools

A technical goal that is necessary to implement the proposed Engineering Studies first year seminar is a proposal and outline for collaboration milestones with the Easton Public School District. The course syllabus outlines the intended weeks that Easton school children visit the Kirby Solar Array for solar education. However, for this collaboration to successfully happen, Lafayette and Easton public schools must be aligned with common goals. The formal proposal is to be sent to the Superintendent of the Easton Public School District to outline the collaboration opportunity.

The Proposal includes:

- Proposal Overview and Introduction
- The Importance of Solar Array Energy Education
- Overview Lafayette First Year Seminar & *Solar! An Array of Energy and Education*
- Goals for Collaboration with Easton Public School District
- Outline of Collaboration with Milestones

See *Proposal* under the appendix to read the full letter to the Superintendent of the Easton Public School District.

Following the delivery of the letter is a meeting with whomever the Superintendent directs communication. The hope is that the proposal leads to a long-term relationship based on solar energy education with Easton Public School district. The relationship helps facilitate a collaboration that develops the FYS and k-12 solar energy education program. More so, the FYS intends to be the first phase of a more extensive facilitation of solar energy education, inspiring peer institutions to do the same, all while contributing to a more informed public.

How an FYS is a Promising Solution

Sustainability Education and Project Based Learning

Solar! An Array of Energy and Education is a distinctive college course, utilizing meaningful local examples to facilitate course material for stronger long-term retention for students. Historically, undergraduate institutions are often reluctant to reform or adjust curriculum. Engineering institutions that work to maintain and excel their prestige and academic excellence are no exception. UCLA, Caltech, Harvey Mudd, and MIT are examples of undergraduate engineering institutions that have experienced significant social and political pressures to reform their technical curriculum, particularly in the 1960s. For instance, UCLA's Education Development Program (EDP) helped to shift the undergraduate postwar technical engineering curriculum to move towards a curriculum that integrated applied humanities.

Even so, changes did not start until after twelve years of the EDP's extensive evaluating, reporting, and documenting of UCLA's engineering program. Caltech is an institution that is not geographically far from UCLA. However, Caltech failed to expand to the degree of UCLA during the 1960s. Part of this can be attributed to the lack of humanities at Caltech. During the backlash of technology, students argued the school's strict technical curriculum created an "alienating culture." In an attempt to make the school more human, Caltech instituted social sciences which lead to experts in technological society as opposed to a more humanities-based curriculum like that at UCLA. Wisnioski writes "the debate over integrating social knowledge into engineering education thus became a debate between the humanities and the social sciences. Social scientists saw Caltech as uniquely poised to create expert policymakers for a technological society." Conversely, Harvey Mudd College (HMC) opened with the sole mission to integrate engineering with the humanities and social sciences. HMC was also the first college to introduce interdisciplinary coursework. *Quest* was a HMC first year program that had a goal for students to understand that "the political, legal and social problems that men had dealt with was as important as suggesting a solution to them." (Wisnioski, 2012, 161-185)

Yet, even when colleges creatively implement non-traditional curriculum, there are challenges that come with it. 1973 was the last year of HMC's *Quest* because faculty felt "overtaxed" and missed the comforts of research, essentials of tenure, and "disciplinary identity." MIT faced urgency for curriculum change from the social pressures of the student body. Students and leftist faculty protested and worked for more social science and humanities courses. Faced with these pressures at that time, the President of MIT commissioned *Creative Renewal in a Time of Crisis* in order to better understand the culture at MIT in order to implement curriculum change within MIT's departments. The political and social pressures exhibited at UCLA, Caltech, HMC, and MIT assist in directing and reforming engineering curriculum. The efforts of these pressures is observed in our very own unique degree at Lafayette College, Engineering Studies. Yet, even so, the challenges of curriculum change at higher education institutions is not trivial, leading often to resistance. (Wisnioski, 2012, 161-185)

Education reform at an undergraduate level faces high levels of both social and political pressures that help to shape and direct educational trends. High schools have more room to creatively explore new avenues for education facilitation. Project Based Learning (PBL) is an example of an education movement that caught on in k-12 schools around the country. According to the Buck Institute for Education, “Project Based Learning (PBL) is a teaching method in which students learn by actively engaging in real-world and personally meaningful projects” (Buck Institute for Education, n.d.). More so, PBL as a teaching method aims for students to “gain knowledge and skills by working for an extended period of time to investigate and respond to an authentic, engaging, and complex question, problem, or challenge.” (Buck Institute for Education, n.d.)

This teaching method first started off in Canada during the 1950s within the context of purely medical education. PBL started to infiltrate the United States during the 1980s and by the 1990s had been applied beyond medical education to higher education and k-12. PBL is particularly popular in graduate level curriculum for business administration, architecture, law school, education, nursing, and social work. While graduate courses often are able to implement PBL, there is still a lack of PBL at an undergraduate level. A benefit of PBL education is its flexibility to be applied within a variety of ability types, ages, and geographic contexts. More so, retention after six months is proven to be six times more effective in PBL methods than traditional methods. (Hung et al., 2008) . Barrows and Kelson developed the PBL curriculum for high school core subjects in 1993 and started a movement of scholars supporting PBL for basic education. Increasing PBL literature reviews and conferences are a testament to the growing popularity of PBL in K-12 education (Hung et al., 2008).

Step 1. Set goals and objectives.
Step 2. Conduct content/task analysis.
Step 3. Analyze context specification.
Step 4. Select/generate PBL problem.
Step 5. Conduct PBL problem affordance analysis.
Step 6. Conduct correspondence analysis.
Step 7. Conduct calibration processes.
Step 8. Construct reflection component.
Step 9. Examine inter-supporting relationships of 3C3R components.

Figure 7: “Breakdown of PBL Methodology” (Hung et al., 2008)

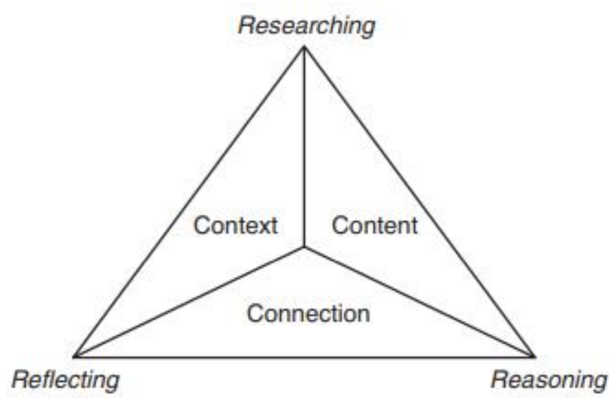

Figure 8: “PBL Design Model” (Hung et al., 2008)

Solar arrays are used to facilitate PBL and meaningful non-traditional education, particularly within the context of K-12 students. Rutland High School in Vermont utilized solar arrays to help students better understand solar array data sets and explore questions relating to climate and engineering. This example of PBL learning is extremely data driven. Similar to the EGRS curriculum at Lafayette College, the students at Rutland High School integrated society, engineering, climate change, and power systems through real world data collected by the arrays. Betts argues that “society makes major changes in our energy infrastructure in response to climate change. We need to accelerate the technical education of high school students using real-world data.” This learning outcome through meaningful education helps reach beyond the classroom to the broader public and aides in the ongoing push to rely more on alternative energy. Education can be a valuable tool to implement solar energy and broader solar infrastructure on a local, national, and global scale, especially when utilizing real world examples like the Kirby Solar Array. (Betts, 2008)

Solar arrays are implemented on college campuses to offset their carbon emission. Arizona State and Ohio state are two examples of this. Yet, solar arrays can be utilized for more than just an alternative energy source. The Kirby Solar Array is a wonderful opportunity to implement PBL within the context of higher education as Lafayette moves to more non-traditional ways of teaching facilitation. Astronomy, Project Management, and Conservation Biology are examples of courses that utilize local spaces to facilitate education in a non-traditional way. Lafarm is an example of Lafayette’s very own facility that is used as an interactive education resource for students that is utilized both co-curricularly and within the Lafayette curriculum. (Lafayette College, n.d.) (Goldfarb, 2016)

Growth, Sustainability Education, and Community

Engineering Studies is a unique interdisciplinary major where students study the relationship between engineering, technology, and society. Because it's a small division under the engineering department, many students and faculty are unaware of the methodology and value of the major. Exposure to Engineering Studies as a mechanism is valuable for any student at a liberal arts college. Adding an FYS under the Engineering Studies division allows for growth in two ways. Firstly, an FYS under the Engineering Studies division allows for more students to be aware of the department for a potential major. Secondly, the students of the first year seminar, per the learning outcomes, are required to learn how to apply a socio-technical lens. This application is relevant to every department at Lafayette College, thus the value of methodology is not limited to students within the major. The implementation of the FYS offers the Engineering Studies department an opportunity to increase its presence on campus whether that means expanding the methodology to students outside the EGRS major or literally growing the number of students who major in Engineering Studies at Lafayette College.

Just like this first year seminar offers the opportunity for the Engineering Studies Department to grow its influence at Lafayette College, it also offers the opportunity for solar energy to grow its influence in the nation. Because of the United States' dependency on fossil fuels, Scholars argue that for the United States to transition to more renewable energy, particularly, solar energy, the United States must prioritize and value renewable energy education. This education is valuable at any age and learning ability, however, is particularly influential for early elementary education. This first year seminar expands Lafayette's curriculum by supplementing its sustainability curriculum to include another class while also extending sustainability curriculum to age groups outside of higher education. (Yogi Goswami, 2001)

Ultimately, this first year seminar is community centered. By extending solar array education to elementary and middle school students in the Easton area, Lafayette is also extending facilities to the Easton Public School District that they would otherwise not have access to for learning opportunities. More so, by having Lafayette students create meaningful lessons for students outside of higher education, the college instills community as a value during the students' very first semester at Lafayette College.

Conclusion

The implementation of the FYS, *Solar! An Array of Energy and Education*, is an opportunity that accomplishes several goals. At a high level, the FYS fulfills Lafayette College's hopes to capitalize on the Kirby Solar Array in more ways than energy conversion. Through the implementation of the FYS, the Kirby Solar Array becomes an important educational tool for Lafayette curriculum. By investing in the FYS, Lafayette College satisfies its responsibility as an institution to educate future generations to be informed citizens and influential leaders are capable of working towards sustainable solutions. More so, Lafayette expands this responsibility beyond Lafayette students and into the Easton Public School District. Ultimately, *Solar! An Array of Energy and Education* is an investment because it is magnetic for prospective Engineering Studies students. By attracting more students to the program, the Engineering Studies division will be able to further its pursuit in the knowledge and exploration of the different socio-technical dimensions.

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Appendix

Letter to Superintendent

Superintendent David Piperato,

Lafayette College comes to you with an opportunity for a mutually beneficial collaboration for the first year students and the students enrolled in the Easton Public School District. The collaboration is centered around education for renewable and sustainable energy sources.

Each first year student is required to take a first year seminar during their first semester at Lafayette College. There are an array of different topics for seminars under different departments at Lafayette College. Until now, Lafayette has not offered a first year seminar under the Engineering Studies division of the engineering department. Engineering Studies is a unique interdisciplinary major where students study the relationship between engineering, technology, and society. This new FYS under the Engineering Studies division offers an introduction to the major through projects utilizing the Kirby Solar Array, a newly built solar array atop Lafayette's sports center. A goal for one of the projects in the FYS is for Lafayette students to facilitate solar energy education to grade school students enrolled in the Easton Public School district.

As educators, Lafayette College and the Easton Public School system have a responsibility to help spread the knowledge of sustainable energy solutions. Scholars argue that, in order for the United States to transition to more solar energy, solar education is imperative. As educators of future policy makers and business leaders, Lafayette has a responsibility to educate students to make informed decisions regarding energy and policy beyond Lafayette College. As educators of the general public, contributing members of society, and future voters, it is the responsibility of the Easton public school district to educate students on solar energy. Scholars recognize the resources that engineering curriculums have regarding solar energy education. Lafayette College hopes to share these resources to help facilitate education to Easton school children, as scholars also recognize the opportunity to develop solar energy education at a lower level.

Seeing that this is a niche topic of study, the Lafayette students of the FYS can utilize the resources at their disposal to help facilitate lessons exposing grade school students to solar energy. One of the most obvious resources at their disposal is the Professor of the course, Professor Nicodemus, whose research focuses on solar thermal technology. Another obvious resource is the Kirby Solar Array. Lastly, FYS students will have eleven weeks of solar energy curriculum, preparing them to help educate and engage the grade school students.

We are open to feedback and, hence the nature of collaboration, hope to gain insight from your perspective on how we can make this a more engaging and meaningful experience for the k-12 students. While we hope you are open to engaging in the opportunity, we also hope to provide clarity regarding the expectations for the collaboration. Firstly, there will be three separate hour-long solar education sessions. These sessions will take place in mid-November/Early December. The k-12 students will bus to Lafayette and each session will take place on top of the Solar Array for a more hands on, meaningful, and memorable learning experience. Before going on top of the Array, the school children will be educated on the safety and behavior conduct expectations. Once on top of the solar array, four FYS students will break school students into groups and start facilitating a lesson that they have prepared ahead of time. Each one of the sessions will take place on a Thursday in November from 11:00AM-12:15AM. Each of the three sessions will be a different group of students. Ideally, each Easton student group is under thirty-five students, engaging in solar energy education with approximately one hundred students than before.

Before the start of the Semester, Lafayette would work with heads within the Easton School District to appropriately choose the three different student groups. Most importantly, we hope the student groups will come from classrooms with teachers willing and able to work with the FYS students to facilitate the education sessions. Each FYS student would be paired with a teacher of each student group. The FYS student contacts the assigned teacher to better understand the comprehension ability of the student group in order to work with the Professor aiding the FYS students to make effective lesson plans. More specifically, the FYS students will work with the teachers to help brainstorm potential lessons that the teachers of the student groups can do in order to expose the students to sustainability and solar energy leading up to the field trip to the array.

While this exposure to solar energy can happen at any age, we recommend, for the purposes of this particular collaboration, that the student groups are grades ten and below, as these will be first year students facilitating the lessons. We also recommend that the pre-exposure to the Solar Array field trip is integrated into the predetermined science curriculum of their grade.

We hope this proposal helped you gain a better understanding of the potential for this collaboration. We hope that you will consider this. We welcome the opportunity to meet to discuss in further detail.

Warmest Regards,

Lafayette College

Course Syllabus

Learning Outcomes: Students will gain exposure to sustainability and solar energy through a socio-technical lens while developing their writing competency. Specifically, students will explore the different dimensions of solar energy including social, political, technical, and economic facets while grounding these ideas through Lafayette's very own array. At the conclusion of the semester, after experiencing the importance of solar education, first year students will work with Easton Public School district to extend the knowledge they have gained to the next generation of contributing citizens.

Below is an overview and breakdown of each class that will make up the fall semester

	Tuesday	Thursday	Topic of the Week
Week 1	Overview of Course Syllabus	Class Discussion Due: Read Lafayette's Climate Action Plan (CAP)	Intro to the course and Lafayette Sustainability

	Tuesday	Thursday	Topic of the Week
Week 2	Climate Change: Principles and Science **Due: 2 Page Synthesis on CAP**	Climate Change: Predictions and Responses	Intro to Climate Change

	Tuesday	Thursday	Topic of the Week
Week 3	Introduction to Renewables (Wind, Biomass, Geothermal, Hydro) **Due: Reading on U.S. renewable energy**	Introduction to Renewables (Solar)	Intro to Renewable Energy

	Tuesday	Thursday	Topic of the Week
Week 4	Introduction to Solar Energy Policy **Due: Reading on solar policy and current events**	Class Discussion & Introduction to Project **Due: Reading on solar policy and current events**	Energy and Policy

	Tuesday	Thursday	Topic of the Week
Week 5	Lecture on the construction and maintenance of solar arrays **Due: Paper on Solar Energy and Policy**	Visit Kirby Solar Array - Discussion on decision to implement the solar array/the construction of it	Energy and Construction/Implementation

	Tuesday	Thursday	Topic of the Week
Week 6	Solar Panels in Industry **Due: Reading on Economics of Solar Panels**	Solar Panels in Industry **Due: Reading on Economics of Solar Panels**	Energy and Economics

	Tuesday	Thursday	Topic of the Week
Week 7	Intro to Environmental Justice & Solar Energy **Due: Environmental Justice Assignment**	Community Engagement and Engineering Projects	Environmental Justice/ Community Relations
	Tuesday	Thursday	Topic of the Week
Week 8	**Due: Paper Synthesizing Community Relations Reading**	**Due: Reading on the impact of education on solar energy**	Solar Energy Education
	Tuesday	Thursday	Topic of the Week
Week 9	Guest Lecture: Delicia Nahman **Quiz: Lafayette Sustainability**	Guest Lecture: Delicia Nahman **Quiz: Kirby Solar Array**	Solar and sustainability at Lafayette
	Tuesday	Thursday	Topic of the Week

Week 10	Technical: calculations on how much energy Kirby array produced	Introduce Project: Assign Easton School Teacher to FYS Students	Applied Lessons
	Tuesday	Thursday	Topic of the Week
Week 11	Education Workshop with Prof. Novello **Due: Contact the teachers of the classes you will be working with. come to class with potential topics to introduce solar energy**	Education Workshop with Prof. Novello **Due: Revised Lesson Plan for School Kids**	Educational Tools
	Tuesday	Thursday	Topic of the Week
Week 12	TBD	Meet with School Kids	Collection of Solar Array Data & Meeting with School Kids
	Tuesday	Thursday	Topic of the Week

Week 13	TBD	Meet with School Kids	Collection of Solar Array Data & Meeting with School Kids
	Tuesday	Thursday	Topic of the Week
Week 14	TBD	Meet with School Kids	Collection of Solar Array Data & Meeting with School Kids
	Tuesday	Thursday	Topic of the Week
Week 15	Class discussion Solar Array Data Findings	**Due: 5 Page Reflection on Course Project with Easton Public Schools**	Conclusion

Table 1.