SOLAR ON STATE: A GUIDE TO IMPLEMENTATION

Nicholas Pratt
Department of Energy & Mineral Engineering
The Pennsylvania State University
221 MRL Building
University Park, PA 16802
nrp5084@psu.edu

Jordan Crolly
Department of Energy & Mineral Engineering
The Pennsylvania State University
221 MRL Building
University Park, PA 16802
jjc5245@psu.edu

ABSTRACT

The goal of "Solar on State" is to install a solar array on The Pennsylvania State University's University Park campus that will provide a clean and renewable source of electricity generation. Providing economic justification for photovoltaics in an area with a moderate solar resource and a very low cost of electricity can be a significant challenge. However, in a creative and educational environment, there are additional benefits to using solar energy that can justify the project, other than energy savings and a reduced carbon footprint. The opportunity to use the solar array as an educational tool in a variety of course curricula provides a major benefit to the university, but this must be planned for in order to maximize these benefits. Another benefit of the project is the publicity the university would receive for its strides towards sustainability, but this must be planned for by installing the solar array in a highly visible location. Multiple sources of funding will be tapped into in order to pay for the initial cost of the project such as the money allotted to the Office of the Physical Plant's Energy Savings Projects, support from colleges who plan to use the array as an educational tool, as well as donations from alumni and corporations, specifically those in the solar field. Solar companies which donate their time to the making the project a reality will have the opportunity to build working relationships with knowledgeable and motivated students through the design and implementation process of the solar array. The "Solar on State" model can be used as a guide to implementation for campuses around the nation.

1.

WORKING WITH UNIVERSITY ADMINISTRATION

Once talk of a solar project becomes serious, the people responsible for approving it must be identified. Universities typically have a dedicated office responsible for the operations and maintenance of the campus. Within this organization exists a group of people who are in charge of accepting and denying engineering projects. It is important to establish a relationship with this group of engineers and facilities managers because it allows for the proposal to be structured to meet their needs. Upon meeting with them, it is important to find out what expectations and limitations they may have, such as keeping the project's budget and payback period within a desired range. Penn State's version of this group is the Office of the Physical Plant (OPP), of which the team met with the lead Energy Engineer and the Vice-President to determine those expectations and limitations. It was learned from this meeting that for OPP to support the project from a pool of money set aside for Energy Savings Projects (ESPs), the simple payback period must be within 8 and one third years. It was also made clear that student led projects like this typically have the full support of OPP as long as the proper procedure and documentation is followed. Additionally, they were comfortable with students being involved in all aspects of the project with the exception that students would not be allowed to actually install the system due to safety concerns and labor policies.

Gaining the approval, and more importantly the support, of the campus administration, facilities managers and engineers is vital to the success of any project, particularly on something they haven't done before such as a photovoltaic installation. It is also a necessary step to understanding the client's expectations and limitations while allowing both parties to voice their concerns and address any areas of uncertainty.

2. CONTACT WITH SOLAR INDUSTRY EXPERTS

Establishing relationships with experts in the industry is necessary to the success of a student led initiative. While seeking the assistance and guidance of university professors is important, contacting those in the solar industry is arguably more important. Companies in the solar industry can be a wealth of information and are often willing to lend a hand, particularly with a student led initiative. These companies can help determine the proper site selection, create an engineering design, and even provide sponsorship and donations to support the project financially.

When contacting solar companies, it is helpful to reach out to both large and small companies because both bring different assets to the project. Larger companies tend to be more willing to donate money and materials, whereas smaller companies tend to be more willing to donate time. Since larger companies typically have a bigger budget, they could potentially supply the racking system, modules and other electrical components without having a significant impact on their company's bottom line. Smaller companies tend to be more willing to donate time since they are usually based locally and often have ties to the university. Local solar companies have experience dealing with the climate in a particular region which will make their designs more suitable for the area.

Once the design is finalized, both large and small companies will have an opportunity to bid on the project. The company that is ultimately selected depends on the wants and needs of the university. The main deciding factor in the university's decision will be the total cost of the project and its corresponding payback period. However, additional considerations may be made based on which companies are willing to educate students during the construction process.

3. SITE SELECTION

When choosing a site for a campus installation, there are some important factors that need to be considered. In general, the site should be large enough to fit at least 100 kW of panels to make the project worth the time and effort. Although larger projects have a larger initial investment, the payback period tends to be quicker due to economies of scale. For example, the installed cost per Watt of a 1 kW system may be on the order of $8, whereas the installed cost per Watt of a 1 MW system could be closer to $4. Additionally, with a campus base load power consumption of 40 MW, the project should be large enough to make a dent in that demand or else it is not worthwhile.

Another vital component of the site selection is making sure it is in a highly visible location while not sacrificing the solar resource. From a public relations perspective, a large scale photovoltaic installation is a major step towards sustainability and environmental awareness. At a university such as Penn State that has significant ties to the oil, gas, and mining industries, this shows the acceptance of the transition from conventional fossil fuels to renewable energy sources. Students, faculty, and community members will be able to look upon a roof and see the photovoltaic array and hopefully feel a sense of pride or at least curiosity as a result of the passionate and dedicated student led effort. With an increased public relations benefit for the university, there may be interested parties or alumni that are willing to donate money to the university for future projects with similar goals.

During the site selection, one thing to keep in mind is balancing the system size and visibility while not sacrificing the solar resource. Shading is one of the most significant factors when deciding how to position and orient the modules. Without the use of micro-inverters or bypass diodes, the partial shading of one module could significantly cut the power output of the array, because the current will be limited to the cell with the lowest current in a series.

After a shading analysis is performed, the desired azimuth and altitude angles for the modules must be calculated. It is a common misconception, even among those in the solar industry, that it is necessary to obtain the exact optimal orientation for a solar array. Of course it would be ideal to orient the array at the optimal azimuth and altitude angles, but often there are structural and shading constraints with doing this, which can be overcome for a cost.

Figure **??** approximates a region with climate and sky clearness similar to that of Pennsylvania, and provides a recommended optimal collector tilt near 36°.(1,2) The Figure displays the sensitivity for deviation from the near-optimal collector azimuth and tilt influencing the annual irradiance for a system. From the diagram, it can be seen that within Pennsylvania an array can have an azimuth angle (γ) between 40° East and West each, accepting at least 90% of the annual resource. Collector tilt (β) can range from 26° and 56° and still

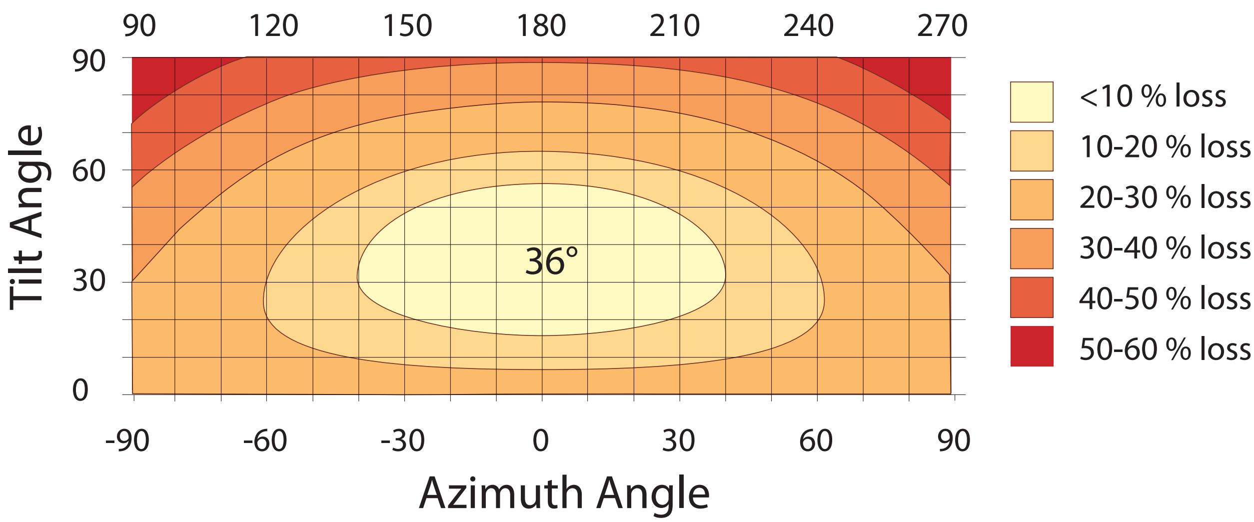

Fig. 1: Illustrating annual irradiation losses for collector tilt and azimuth deviations from an optimal state of $\beta = 36°$ and $\gamma = 0°$. For tilts from $\beta = 26°$-$56°$ and azimuths up to 40° East (negative) or West (positive), the annual irradiation losses are only estimated to be 10% of the optimum. Graphic adapted from Christensen and Barker, 2001. Used with permission from J. R. S. Brownson.

accept at least 90% of its annual potential.

Based on **??**, using the optimal orientation should not necessarily be the top priority. Instead, it is more important to minimize the installed cost by using azimuth and altitude angles that can be easily implemented onto a building. As long as this alignment does not have any significant sources of shading and falls within a tolerable range of deviation from the optimal angle, the array will produce near the maximum energy output for its given location.

4. FUNDRAISING

The installation of a photovoltaic array that produces power on the order of 100 to 500 kW can be very expensive for a university. State funded universities, like Penn State, are tax exempt, and therefore are ineligible for tax incentives on the state or federal level. Based on this lack of incentives and other factors, the amount of time it takes for the solar array to pay back its initial cost is significantly longer than similar projects which can take advantage of government incentives.

The major factors in determining the payback period is the initial cost, the annual energy produced by the array, and the university's cost of electricity. Penn State currently pays $0.06/kWh, which is quite low relative to other universities and locations throughout the United States. For example, a 200 kW photovoltaic system installed on Penn State's campus would cost roughly 1 million dollars and have a payback period longer than the projected life of the system without incentives or an escalation in electricity costs.

Penn State's electricity cost is quite low relative to other parts of the nation so other universities should have a shorter payback period. Nevertheless, it is very important to explore fundraising and financing options when implementing an engineering project of this magnitude. Solar companies are not the only source of donations that should be considered. Internal sources of funding such as individual colleges within the university that could benefit from the project should be explored as potential donors as well.

Another potential funding source is through the alumni network, particularly those with ties to solar or sustainability in general. The first step is to draft a letter to alumni seeking financial support for the project and getting this letter approved through the alumni office. The second step is to gather support for the project from organizations within the university, which will give the letter much more credibility. When gathering support from campus organizations it is important to reach beyond just the sustainability minded organizations, and to reach the leaders of various other organizations. This will show that the support for this project is very diverse and widely supported by the entire student body.

It should also be mentioned in the alumni letter that there is potential for the array to be named in honor of the highest donor, if they so choose, and that all financial supporters of the project will be recognized by a plaque near the installation site. Donations from large corporations is another possible source of funding, and to increase this it may be wise to ask these corporations to match the amount raised through other methods. If done well, this has the potential to be the largest chunk of funding for the project. In the same way that the top supporting alumnus can have the array named in their honor, so can the top supporting corporations. Additional reasons for large companies to donate to the project include the public relations benefit associated with supporting student led sustainability efforts, but more importantly the tax incentives from tax breaks associated with the donation.

5. EDUCATION

A photovoltaic array on a university campus can have a variety of educational benefits. Promoting the array as an educational tool will make the decision easier for university administration to implement a solar project even if it does not quite make economic sense. There are many courses spanning several subject areas that could integrate the data generated by the solar array into their lesson plan. Courses ranging from business, to engineering, to liberal arts, could use this data in educational exercises specific to their courses. Any university that invests in photovoltaic arrays will be able to develop lesson plans and educational pieces tailored to specific audiences.

It is important to work with the university administration to allow students to be educated during the planning, design, and construction process of the project. Students could greatly benefit from seeing all aspects of the project from conception to birth. Also, the project should be documented in detail simply to allow future students the benefit of learning the planning process of an engineering project such as this. This guide should include the obstacles encountered and how they were overcome. It is most likely that students will not be allowed to supply manual labor, but will be allowed to contribute in all other aspects of the project. As a reference, Penn State's Office of the Physical Plant has agreed to allow students to work on the planning and designing process, as well as post construction monitoring, however using students as a cheap labor force was strictly forbidden.

The data collected from the array can be incorporated into various science and engineering classes. Depending on the specific class, different lesson plans can be developed. Classes in architecture could use the array as a prototype to design their own system for another area. Students could design buildings with the knowledge that arrays should generally be oriented due south and tilted to the latitude angle. The array could also be useful to electrical engineering courses in a lab setting by taking measurements and performing calculations. Various classes could take advantage of real time data collection of short circuit currents, open circuit voltages, and power production of the system.

Courses that specifically cover photovoltaic systems would benefit greatly by having access to a system installed on their campus. Students and professors could monitor and analyze the data which could then be used in the classroom as an educational tool. Students could use shading analysis tools such as the solar pathfinder, Solmetric SolarEye, and others to determine if the array receives any shading throughout the year. Students will be able to measure the output in the array and any trends associated with it. For example, through analysis, students will find that a decrease in ambient temperature will increase the power output of the array at constant irradiance.

Students can also experience how daily, monthly, and yearly irradiation affects the array's output. Photodiodes or other irradiance detecting devices should be placed on site so that students can easily access this data. Penn State is lucky enough to have a SURFRAD station not far from campus. SURFRAD stations are NOAA's Surface Radiation Budget Network, which contain devices that measure and interpret solar irradiation and weather data at different locations in the United States. Using this data in conjunction with data from the array can give students a clear understanding of how irradiance and power correlate.

Penn State has several courses that are focused on photovoltaic systems, including Architectural Engineering 498 and Energy and Geo-Environmental Engineering 437. The former course uses small indoor lab demonstrations as a means of teaching the material. The latter class has a final project in which students are required to design a system using the System Advisor Model (SAM). While both classes are great for learning about solar, neither employs real arrays into the learning experience. Therefore, implementing a solar project on a college campus would vastly improve the students' education and enjoyment.

One valuable tool for a photovoltaic system analysis is the National Renewable Energy Lab's program, SAM. This program allows users to input a range of variables about the array and outputs financial and energy data. SAM allows for users to input financing options, incentives, array size and specifications, shading, utility data, and weather data. Using this program, students can enter the specifications of their university's array and compare the projected output to measured data. This will allow students to gain an in depth understanding of the SAM software as well as develop critical thinking skills when trying to determine any discrepancies between the projected output and the actual output.

Economics and energy finance courses could integrate the data and specific project details into a case study. Students could use the data to calculate the likely payback period, internal rate of return, and the net present value, which can again be compared to SAM's projected values. Different financing options, such as Power Purchase Agreements, can be explored to determine if their university chose the best option, and provide advice on which financing option should be used for future projects. Additionally, this project could be used as an example to demonstrate how the SREC (Solar Renewable Energy Credit) prices affect the solar industry.

Courses related to sustainability and climate change could incorporate the data into a discussion about greenhouse gas emissions. Using this data, students could learn to calculate the amount of carbon dioxide emissions avoided through the replacement of fossil fuels. Another study topic for students could be to complete a life cycle analysis of all the elements of the array to determine greenhouse gas emissions, energy consumption and energy production.

The educational aspect of a photovoltaic installation offers a chance to instil a new appreciation for solar energy that a student might not experience otherwise. Analysis of live data from solar arrays puts in place a new possibility for course curricula, with students who have a new appreciation for solar energy, sustainability, and the future of energy resources.

6. CONCLUSION

Gaining the approval and support from the administration is the first step to successful solar project because it allows the expectations and limitations to be established from the beginning. Getting help from professionals in the solar field is important for many reasons, such as building relationships with solar companies and insuring a quality project. Selecting the site of the solar array can also be challenging because of the balance between finding an area large enough to support 100 to 500 kW, while minimizing shading and construction costs, and maximizing the arrays electricity production and visibility. In order to make the project a reality it is important to pool from multiple funding sources such as the university's Office of the Physical Plant, colleges that plan to integrate the array into their courses as an educational tool, and donations from alumni and corporations with ties to the solar industry. The hands on educational opportunities associated with having a solar array on campus likely provide the most influential justification for the project because it will allow cross disciplinary education of concepts tied to the solar industry. The "Solar on State" project can be realized while providing many benefits that promote the mission, vision and values of the Pennsylvania State University.

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8. REFERENCES

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