Abstract

The feasibility of implementing energy sustainable projects that engage students on the Penn State University Park Campus was investigated in this report. Solar panels, wind generators, vegetative roofs, and kinetic energy panels were studied to determine which would be the most effective on the University Park campus based on area available, funding, available maintenance support, and current student interest. It also looked at how to increase public awareness of sustainability by involving the students, faculty, and staff of Penn State in the implementation of such a project.
Executive Summary

This report examines four possible projects that will help Penn State engage students in reaching its goal of sustainability by minimizing emissions and waste generation. Research was conducted on the implementation of wind turbines, solar panels, green roofs, or kinetic energy harvesting panels on the Penn State campus. Each technology was judged based on associated costs, availability of campus space, presence faculty with expertise in related field, staff support, and student involvement.

Associated costs were calculated by considering the initial costs of purchasing and installing a technology and then computing the time period for return on investment (ROI). Green roofs were found to have the shortest ROI period while kinetic energy panels the longest. Plenty of space was identified for each of the projects. The University Park campus has 79 acres of rooftop space that could be used for wind turbines, solar panels, and green roofs. Meanwhile, there are over 25 miles of paved sidewalks for the kinetic energy panels. Faculty expertise in each of the technologies would be crucial to their successful implementation and continuous operation. Solar panels were deemed to need the least Faculty guidance as this technology have been available for years, while projects involving wind turbines, kinetic energy panels and green roofs would need knowledgeable faculty member guidance. All of the projects would need the support of university Staff in their construction and maintenance. Solar panels and wind turbines would require the least amount of Staff support, followed by green roofs, and, lastly, kinetic energy panels due to their location in high pedestrian traffic areas. Direct student involvement in a project is crucial for creating future leaders that are aware of sustainable practices and technologies. Kinetic energy panels were found to cultivate the most desire for involvement from students due to their ability to directly participate in energy generation. Meanwhile, solar panels were thought to see the least participation due to their static nature.
A Scoring Matrix was used to determine the most feasible project. Each of the aforementioned criteria was rated on a scale of -3 to 3 based on our research. Weighting factors were assigned to each of the criteria based on perceived importance. The product of the rating and weighting factor were taken for each criteria and summed to yield a final score. According to this method vegetative roofs were the most feasible followed by solar panels, kinetic energy panels, and wind energy turbines.

Based on these results a list of recommended courses of action for Penn State was created. Each action is necessary for the University Park campus to continue actively improving the energy usage on campus and directly involve the undergraduate and graduate students in this. The actions directly related to vegetative roof implementation should be completed first, as it was determined to be the most feasible for the university. This includes instituting a course or research project, tied to a project advisor, to design and construct green roofs at the University Park campus. Other action should be taken to promote student involvement and interest in developing solar panel and kinetic energy harvesting panel arrays.
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1 INTRODUCTION

"Sustainability will be an important peg on which we will hang the expansion of experiential learning at Penn State, encouraging our students to positively impact the communities they touch (Learn, 2016)," Vice President for Student Affairs, Damon Sims, declared in advocating for the implementation of more sustainability projects at the Pennsylvania State University. Here, and throughout this report, "sustainability" refers to environmental sustainability, or the ability to maintain qualities of the physical environment such as maintaining the quality of life for people, existence and functionality of ecological systems, and existence of renewable energy.

The Sustainable Strategic Plan at Penn State was created under the guidance of Provost Rodney Erickson during 2011-2013 and one result of the report was the development of the Sustainability Institute. The mission created by this strategic plan is centered around helping people realize the need for action, utilizing the knowledge and innovation of Penn State community members to create solutions, and leading the world towards developing more sustainable lifestyles. Penn State’s goal is to reduce emissions by 35% of 2005 levels by 2020. To combine both this and the university’s goal of promoting sustainable leadership, several projects, and the feasibility of each, have been explored in this report.

Possible projects incorporated renewable energy sources and/or various sustainability practices. Examined renewable energy sources consisted of wind turbines, solar panels, and kinetic energy tiles, while sustainability practices included vegetative roofs. Such technologies and practices would help Penn State achieve its goal to reduce emission and waste generation.

1.1 Methods

In order to conduct this feasibility study, various experts in the field of energy and sustainability, as well as OPP (Office of the Physical Plant) of Penn State were contacted. An interview with Doug Goodstein, the student programs coordinator for the Sustainability Institute at Penn State,
was conducted. This research and information collected through interviews allowed projects to be evaluated by their associated cost, available campus resources, and appeal to the student body and faculty. These evaluations were analyzed in a scoring matrix. This allowed the team to recommend a course of action for the university for each project.

1.2 Structure

The structure of this report follows the aforementioned criteria. Each project and the cost associated with implementing a renewable energy technology or sustainability practice on campus is explored. An examination of the resources already available at Penn State that can make integration of the suggested project easier is provided next. Finally, the disposition of Penn State’s students and faculty for supporting the project is taken into account. Based on these criteria, compiled into a scoring matrix, a recommendation for a sustainability project is made.

2 PROJECTS

The four unique projects evaluated in this feasibility report are described in more complete detail here. They are to include a wind energy research lab, solar panels placed on campus building roofs, kinetic energy panels incorporated in heavy traffic sidewalks, and public accessible vegetative roofs.

2.1 Wind Energy

Integrating wind turbines on buildings is a focused area of renewable energy that would benefit from more research. Projects such as AeroVironment’s Architecture Wind, Figure 1, "provide a visible, compelling and architecturally enhancing statement of the building’s commitment to renewable energy (Architectural Wind, n.d.)." Unfortunately, due to lack of development, the turbines have not been optimized for use on buildings and are rarely used commercially.
Figure 1: AeroVironment’s Architectural Wind Project

This is a project that would include undergraduate and graduate level courses. Students a part of the project team could take courses such as Penn State’s AERSP 886: Engineering of Wind Project Development and work in interdisciplinary teams of architectural engineers, aerospace engineers, electrical engineers, meteorologists etc.. With faculty advisors, this student-group would design a turbine and select the prime buildings on campus to analyze and develop solutions for the commercialization of wind turbines on buildings. Existing wind turbine technology could also be purchased for students and faculty to perform research on as they are developing new solutions.

2.2 Solar Panels

The Pennsylvania State University 2015 class gift is an array of solar panels. Almost $200,000 was donated to support this project and place panels at a location such as Stadium West Parking lot (Class Gift Campaign, 2015). This is a project that has grabbed an impressive amount of support and will provide support in Penn State’s mission to get more of its energy from renewable sources. It does not, however, include students in the design process except for proposing ideas for locations.

The solar panel arrays discussed in this report instead include arrays on building roofs instead of on the ground. They would be installed professionally on roofs around campus oriented properly to optimize the capture of energy. Student interns could assist the Office of Physical Plant (OPP) and housing to do analysis on the structure, orientation and space of available class, research and
dorm buildings on campus. OPP would require support for this and it provides opportunities for students to be more thoroughly involved.

### 2.3 Kinetic Energy Panels

Pavegen is just one company that supplies kinetic energy transferring panels. These panels harness energy from every footstep taken on them and utilizes the energy to power low-energy LED street lighting or to provide energy for off-the-grid charging stations. This project would be similar to the phone-charging station at Webster University seen in figure 2 or the stadium light-powering tiles placed under the soccer pitch in Rio de Janeiro (Shell Football Pitch, 2015). Tiles would be placed directly on a frequently-traveled sidewalk, such as on Pollock Rd. outside of the Hetzel Union Building (HUB) or placed under an IM field to power the stadium lights near the Law Building.

### 2.4 Public Accessible Vegetative Roofs

A vegetative roof, otherwise known as a green roof, "is a planted roof top that provides benefits of water harvesting, stormwater management, energy conservation, pollution abatement, and aesthetic value (University of Florida)." Penn State’s University Park campus currently has four green roofs, including the recently finished one at the HUB student center. All but the HUB building roof were designed and constructed by OPP and students in HORT 497B, a hands-on course on
vegetative roofs that was taught from 2005-2008.

This project would include revamping this course, and incorporating students to design, build, and maintain the green roofs on campus. Green roof space would be planned into new and renovated building designs and a majority of these would include study spaces for students not directly involved on the project.

3  PROJECT NEEDS

Project criteria were compiled after reviewing Penn State’s mission for sustainability as presented in the Sustainability Strategic Plan and discussion with Doug Goodstein, student program coordinator at the Sustainability Institute. These characteristics have been evaluated for each project and analyzed below.

Table 1: Project Criteria

<table>
<thead>
<tr>
<th>Needs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Funding</td>
<td>Must fund project upfront or return on investment</td>
</tr>
<tr>
<td>Physical Space</td>
<td>Space utilized must not interfere with general university function</td>
</tr>
<tr>
<td>Faculty</td>
<td>Experts should be available to advise/mentor students</td>
</tr>
<tr>
<td>Staff Support</td>
<td>Divisions such as OPP need to help construct and maintain it</td>
</tr>
<tr>
<td>Student Involvement</td>
<td>Students must be engaged in implementation and usage</td>
</tr>
</tbody>
</table>

3.1  Funding

The two main factors determining the economic feasibility of these four projects are the scale and location of their implementation. Project scale is directly proportional to the capital and maintenance costs. Location would determine each project’s efficiency which is proportional to monetary
savings made due to a reduction in the use of energy or other resources. The efficiency is also linked to the rate at which the project finances itself.

Wind speed and persistence scales proportionally to height above ground. The optimal height for wind turbines is around 150 ft (Christiner, 2010). Even the highest rooftop on campus (Oswald building at 124 ft) is too low to meet this wind (Fast Facts on The Pennsylvania State University). The average yearly wind speed at a height of 80 m in State College is around 4.5 m/s and would be significantly lower near campus rooftops (Pennsylvania Wind Resource Map and Potential Wind Capacity). Lack of sustained wind translates to lack of power production. With a 400 W rooftop turbine, such as the Primus AIR 40 costing at least $800, for purchase and installation, and the average price of a kWh in SC being $0.0746, it would take 3 years of constant operation at maximum power generation to start seeing returns on such investment (Lombardo, 2015) (State College, PA Electricity Rates). If such a turbine was implemented at 80 m in State College the return on investment period is calculated to be about 40 years.

The cost associated with solar panels has a similar dependency on their environment. With the ability to generate 11 W/ft², a one square foot solar panel would generate 96.4 kWh per year (assuming there is always sunlight for 365 days or 8760 hours). With a capital and installation cost of 12.5 $/ft² it would take 1.7 years to start seeing returns on the investment using the cost of a kWh in State College (Friedman). A cost adjustment based on the the climate of the location in which the panels are to be used can be made by accounting for the average number of hours that the site receives sunlight in a year. State College has an average of 178 sunny days per year (Sperling). Assuming the sun shines for 12 hours on each of those days this would mean 2,136 hours of sunlight per year (Average Weather for University Park, Pennsylvania, USA). The site adjusted time period for return on investment would be 7 years.

Kinetic energy panel technology consists of floor panels which are made from piezoelectric materials. When subject to mechanical stress such as footsteps, these materials generate an electric
charge that can be used to create a current of electricity. This electricity can immediately be fed to the grid for use or stored for later in batteries. In the past few years a company called Pavegen has tried to commercialize this technology. They have debuted their 0.6 m x 0.45 m tiles at events such as the Paris Marathon were 40,000 runners had the potential to step on tiles laid throughout the track (Morales, 2013). The idea behind these tiles is that they would be placed in high traffic areas to generate energy. Pavegen has claimed that every footstep can generate 7 watts of power with a tile costing $200 as of 2013 (Williston et al., 2013). If one tile was placed inside the HUB on the UP campus and saw 40,000 steps daily with each step lasting 0.5 s, annually, this tile would produce 14.2 kWh of energy. At such a generation rate it would take 189 years to see any returns on investment.

Monetizing the benefits of green roofs is difficult due to their unique interactions with the biosphere. However, there are multiple economic incentives associated with installing green roofs over conventional rooftops. Green roofs are better at insulating homes than conventional rooftops, as a result, saving the occupants save money on heating in the winter and air conditioning in the summer. Although they have higher capital costs, green roofs have been found to last three times longer than conventional rooftops, saving occupants money on roofing overtime (Berghage et al., 2007). A cost benefit analysis done by the US General Services Administration found that over a 50 year period green roofs have a net present value of over 70 $/ft2 with a return on investment period of about 6 years (2011). These estimates are applicable for nationally. For a more accurate cost analysis specific site assessments (average yearly rainfall, current building roof material, etc.) have to be made.

### 3.2 Physical Space

According to the Penn State Schreyer Honors College website, "...more than 25 miles of paved sidewalks crisscross Penn State’s University Park campus" (Penn State Schreyer, 2016). This allows for plenty of room to incorporate kinetic energy transferring tiles into the walkways on
campus. They are placed flush into a sidewalk and do not interfere with normal transportation, except during construction.

The solar panel array, vegetative roofs, and wind energy generators all require roof space. The Office of Physical Plant (OPP) reports 79 acres of total roof space (OPP 2016) throughout the entire campus. Solar panel arrays generally need to be oriented towards the south such that they optimize the solar energy captured. This cannot be accomplished on all buildings, such as roofs angled away from the optimal. Vegetative roofs generally require flat roofs as well to take full advantage of stormwater capture, insulation, and proper drainage. They must also be able to handle the loading of the water and soil retained and most buildings constructed under modern standards do not have to be reinforced. The available, flat roof space that is safely accessible on campus allows for the support of solar powered arrays or vegetative roofs without taking away from space currently used by the university.

3.3 Faculty

Faculty have an important role at the Pennsylvania University. They exist to constantly learn and develop in their field of technical expertise for the benefit of themselves, the university, the world, and the students at Penn State. Courses with numbers ending in -97 (i.e. 397, 497) are defined as "formal courses given infrequently to explore, in depth, a comparatively narrow subject that may be topical or of special interest (University Bulletin, 2016)." These courses are dependent on the faculty who have knowledge in the special interest the class focuses on. HORT 497B was a course offered from 2005-2008, exposing students to green technologies such as vegetative roofs. They explored functions of green roofs, especially in storm water mitigation, and worked on a major project including the construction of several green roofs on campus and at a local elementary school. This course disappeared, however, when the faculty member who instructed the course started research and focus in a new area. No one else held his technical expertise in green roof technology.
The green roof and wind turbine projects both require dedicated faculty members. They would need to serve as instructors, technical experts, research advisors, and well as the administrative role of outreach and finding funding. Kinetic energy panels and solar panels could be largely handled by dedicated students and mentors from the Sustainability Institute. This makes the latter projects less susceptible to discontinuation. They do not depend on technical expertise that may not always exist at Penn State or might not be readily available.

### 3.4 Staff and Offices

A university consists of more than just faculty and students. Staff offices such as OPP and housing are a critical portion of education and have a direct impact on a student’s quality of education. Their support is necessary to maintain any project at the University Park Campus.

Unfamiliarity is often one of the largest barriers to overcome for a project. Each of the projects discussed in this report require more personnel and time from OPP. The solar panel array and green roofs would require less accommodation as similar projects have been completed before. Maintenance is minimal on vegetative roofs, often requiring minimal care a couple times a year (Jarrett, 2014). Wind turbines should not require maintenance after initial installation but might interfere with general care of the building.

Construction of all four projects will require management from personnel within OPP. Installation of the kinetic energy transferring tiles are most intrusive to the general function of the university. They will require removing parts of the sidewalk they are to be implemented in or removing and replacing turf grass if they are to be integrated into a stadium or IM field.
4 COMMUNITY INVOLVEMENT

Penn State supports projects and research that pursues energy sustainability. These projects are limited in their involvement to the students and faculty directly working on the project. More work must be done to integrate sustainability into the everyday workings of the campus if Penn State wants to invest in creating students who will leave this campus and be leaders in sustainability in their communities.

One project that has successfully done this is the Mobius project conducted through the Sustainability Institute of Penn State. This initiative brought options for composting and recycling right into the hallways and classrooms where the students and faculty were. Through these efforts by the institute, in 2014 total waste came to about 14,163 tons, 7,991 tons of that waste was either recycled or composted instead of being sent off to the landfill, about 56% of the total waste. By adding composting bins throughout the university park campus, an estimated 4,315 tons of organic matter was composted instead of going to the landfill. This makes up nearly 30% of the total waste stream (Mobius, 2013).

4.1 Barriers to Involvement

Involvement is all about the learner and learning environment. The more connected the cause and effect of a person’s actions are, the more likely they will feel the need to be involved. The Mobius project is not more successful than it already is because a student does not see a direct impact from their decision to direct waste away from landfills. Most will only recycle if it is convenient for them. If a student already has an idea, he/she will often not have enough support to go beyond the design stage. Penn State has opportunities for inspiring innovation through project and presentations but there are not groups set up for seeing projects through. Students are easily discouraged once they hit a road block and often do not have enough support to be persistent and work around the barriers they will face.
Figure 3: The Transtheoretical Model

Co-curricular learning should be an integrated part of the campus. The Transtheoretical Model of Behavior Change, Figure 3, is a device to assess an individual’s readiness to change one behavior, for a new, healthier one. Contemplation would include a student seeing the kinetic energy charging station able to charge their phone after they step on the tile. Even though it is really the culmination of hundreds of footsteps that allows the phone to be charged, this student may want to work to have kinetic energy transferring tiles implemented all around campus after seeing the potential for the technology. Between preparation and action, this student gives up because there is not funding directly available and no one on staff has invested to mentor this student. One of the largest barriers to student involvement is offices such as OPP, maintenance, and housing do not see their role as educators. Everyone at the university is an educator and have a role in a student’s education.

4.2 Implementation

A major part of student involvement should be during the implementation, or design and construction of a project. This allows students to be a part of the problem-solving required to develop technology for and push for the resources for a project.
The solar panel array should directly involve students to select the location, design the orientation, and work with the university, OPP, and companies for installation. The wind turbine research provides excellent opportunity to directly involve students in the research of existing technology and development of new technology. The course in vegetative roofs, like previously available, would also provide this direct student involvement in learning practices for green roofs and directly applying this learning in a way that benefits the student and university. The kinetic energy panels would involve students in the design of the project. An interdisciplinary project group would work to select a project type, such as a charging station or integration in a IM field, and design the arrangement of tiles.

4.3 Participation

There are a few different ways to go about involving students, faculty and staff of the university as the project is implemented into everyday, university life. Directly involving students is a main method of motivating them to take their own action to help develop the project further. Another way is to raise awareness so that students will begin to initiate their own project and sustainable ideas at the university and in their future communities.

The Student Farm is an example of successful implementation of direct involvement. The student farm initiative was started by students in the college of Agriculture in 2015 and will be continuing in the future. This is an effort led by students for the university where the students will maintain and monitor their own farm plot just outside of the University Park campus (Student Farm, 2016).

Each project discussed in this project, to meet the needs of the university, has to engage students throughout the lifetime of the project. The kinetic energy panels allow the most direct involvement for students. They allow an immediate visual of the cause-effect relationship between the student’s involvement, stepping on the panel, and outcome, charging of a phone or stadium light staying on. The solar panels allow no direct interaction once installed. The wind turbines allow continual
research for only the students involved in the lab or class corresponding. Study spaces can be integrated into the vegetative spaces and allow students to interact and benefit directly from the green roofs. Keeping students engaged and excited for the project is critical for its success in its ability to inspire new projects and leaders for sustainability.

5 CONCLUSIONS

Table 2 displays all the information discussed in above sections to be able to evaluate the feasibility of each project. The weights for each criteria were based on the importance of each factor to the research question. Student involvement was given the largest weight of ’8’ while staff support and faculty, given weights of ’5’ and ’4’ respectively, were important to the support but not overall goal of the project. The total scores are listed towards the bottom, along with which projects are feasible for implementation.

Table 2: Concept Scoring Matrix. Scores range from -3 (poor relative performance) to 3 (excellent relative performance)

<table>
<thead>
<tr>
<th>Selection Criteria</th>
<th>Solar Panels</th>
<th>Wind Energy Turbines</th>
<th>Kinetic Energy Panels</th>
<th>Vegetative Roofs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Weight</td>
<td>Rating</td>
<td>Score</td>
<td>Rating</td>
</tr>
<tr>
<td>Funding</td>
<td>6</td>
<td>2</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Student Involvement</td>
<td>8</td>
<td>-1</td>
<td>-8</td>
<td>2</td>
</tr>
<tr>
<td>Physical Space</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>-1</td>
</tr>
<tr>
<td>Faculty</td>
<td>4</td>
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<td>-2</td>
</tr>
<tr>
<td>Staff Support</td>
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<td>-2</td>
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<tr>
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<tr>
<td>Feasible</td>
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<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Alternate</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

As shown in Table 2, the Vegetative Roof project is the highest ranked based on the criteria evaluated in this paper. It is most able to solve the university’s problem of investing in students to be sustainable leaders while being feasible due to funding, space, faculty, and staffing support con-
straints. Solar panels and kinetic energy panels are also feasible and meet the research problem, but will require more investment of time and staff to be successfully implemented. Wind Energy Turbines, based on a lack of economic sustainability and staffing support to implement and maintain the turbines, are not seen as feasible as a project at Penn State.

6 RECOMMENDATIONS

The Pennsylvania State University at University Park should engage students in energy sustainable projects through the recommendations listed below.

- Implement a course or project club in the Horticulture Department focused on the design and creation of green roofs
- Connect students to staffing groups such as OPP to help design vegetative roofs and learn how to maintain them
- Set-up competitions in colleges such as the College of Engineering to design the solar panel and kinetic energy panel arrays. This should include the location, orientation, and number of panels
- Promote projects like the kinetic energy panels as project ideas for the Class Gift Campaign
- Use the Department of Energy and other groups for sustainability to find research grants to fund vegetative roof research or implement more solar panels around campus
- Discourage the dismantle of energy sustainable projects connected to courses that are discontinued. Fund student groups to continue the projects tied to these classes without a direct course adviser
7 REFERENCES

Title page image from http://www.prweb.com/releases/Hershey_Childrens/Hospital_LiveRoof/prweb10192342.htm


Student Farm, Growing Engagement with our food. (2016). Retrieved March 28, 2016 from http://sites.psu.edu/studentfarm/
