The Case for Sustainable Engineering in Undergraduate Engineering Education

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Abstract

Private sector and government programs represent investments of billions of dollars in the renewable energy field, which is experiencing unprecedented demand. There are many reasons for this demand including that it is a constant growing field due to the need for alternative generation means to address peak loads and to meet carbon reduction goals, among others. Renewable energy technologies are important on a global basis due to pressures on conventional fossil-fuel energy resources used to power the majority of today's societal needs. This dramatic shift means that there is a new need for Sustainability Engineers who are proficient in the broad portfolio of technologies and analytic techniques to deal with renewable and alternative energy. In order to meet increasing demand, Sustainability Engineering students will need to be trained to design new systems as well as plan for the financial aspects of these systems. In most programs, undergraduate students do not have the preparation needed to become effective in the Sustainable Engineering field. For example, they lack coursework in topics such as energy management, generation design, techniques of financial modeling, and exposure to the broader concepts of alternative energy. One of the traditional steps is to create new programs to meet a specific need. Alternatively, concentrations in a new subject can be addressed by formulating a core body of knowledge. An even faster way to begin focusing content on a new area is to adapt existing coursework that is intrinsically flexible; for example, using capstone design and special topic electives. To meet the need for developing Sustainability Engineers, Rowan University is using the Engineering Clinic program to bring together both undergraduate and graduate students to work on projects directly related to Sustainability Engineering. The Center for Sustainable Design located at the South Jersey Technology Park was created to focus on a broad collection of sustainable engineering projects primarily in the photovoltaic and wind energy areas. Typically, projects are one to two years in duration, so students are likely to join a project that is already underway. Inside of the solar category, a task that has been frequently recurring is the performance of the photovoltaic systems as well as taking part in solar assessments for different site areas for companies. While inside of the wind category, students are taking data from several different wind assessment locations in New Jersey and providing possible turbine generation results. The mast anemometer was just another wind assessment location that we predicted the possible amount of power the different turbines would generate.

Background

The College of Engineering at Rowan University has an educational structure termed the Engineering Clinic that emphasizes both project design and implementation as well as technical communication skills. Students at Rowan University use engineering tools to complete projects dealing with real world issues in organized student teams, while also gaining experience with speaking and writing skills through the assigned work.

Society's need for more engineers has shaped the way the Clinics are conducted at Rowan University. Students are challenged to apply a set of skills they have learned—and learn new ones—to solve given problems. [(1)]. In order to meet the demand of Sustainability Engineering, students will need to be trained properly in the field. Designing new systems as well as understanding the financial attributes of the systems are both equally important in the success of a Sustainability Engineering. In most cases undergraduate students have backgrounds that lack certain fundamentals such as energy management, architecture design, sales, equipment management and alternative energy training.

Solar Assessment

Students at Rowan University are given a choice of clinic projects. This gives students an opportunity to pick projects that reflect their interests. We have been able to offer a number of photovoltaic (PV) system projects, which in aggregate offers a suite of sustainable energy projects. Students are split into multidisciplinary teams in terms of some ME, ChE EE and CEE. One of their first assignments is to conduct a small solar assessment of a residential building of their choice and report their findings. Students work in teams to collect as much data on their site as possible in order to determine if the site is feasible to use for solar energy. There are a number of things that must be evaluated including roof orientation, roof angle, roof condition, local shading areas, and total usable roof area. Once these questions are answer, they select the best site in the team to complete their solar assessment. Google Earth or Bing maps are two online tools which can aid a student in the assessment by giving them a visual aid to further assess the site. PV Watts calculates the energy output per month that is produced based on a simulation of the photovoltaic systems connected to the local grid at the specified latitude. This software can be used to determine energy production based on any area in the world. The known electricity price rate for the site can also be entered into PV Watts, for example cents/kW. This will permit calculation for the amount of money that will be saved by installing the designed PV system. [(2)]

After the survey work is done, students prepare a report to be used by other clinic teams as well as Clinic Professors. This helps all the students learn ways to improve their assessment based on work done by the individual clinic team as well as improve the student's presentation skills. Once students have finished the research part of the solar assessment, they are ready to engage the physical part of this assessment. The clinic team physically visits the sites to conduct a solar assessment. The use of a Solar Pathfinder [(3)] is common tool used in most solar assessments. Solar Pathfinders are used to determine the solar window for any given area, hour of the day, day of the month, and month of the year. Results of their assessments guide the recommended size of PV system to match the demand. Proposals include estimated costs for the system and information about Federal and State incentives and rebates in order to explain how these systems can be affordable. The students also determine what the payback is for each system. At the

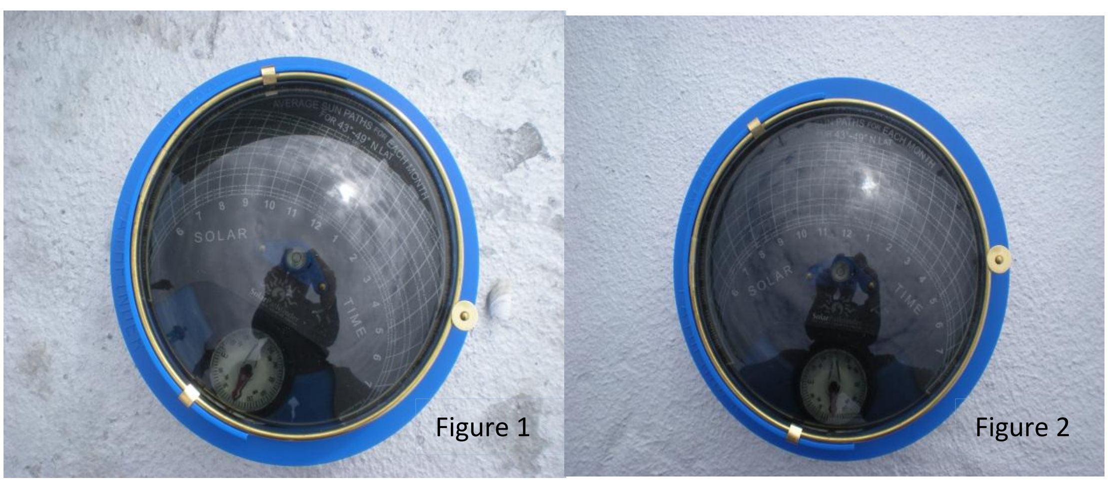
Sophomore Clinic level, some students are given an introduction to the field of sustainability in order to better prepare them for the advanced portion of the junior/senior Clinics.

Harvey Cedars Bible Conference Solar Assessment

At the end of 2010, Harvey Cedar Bible Conference in Long Beach NJ requested from Rowan University that an energy audit assessment be conducted for their facility. The company wanted to explore the option of investing in renewable energy in order to save money on electricity for their facility. Harvey Cedars is a hotel resort that receives most of their guests during the summer time, which is at peak energy cost. There are a number of different factors that affect the cost of electricity in each area, for example: the cost of power plants, the maintenance cost of the local grid, weather restrictions for the area, and even access to fuel sources. Generally the price of electricity will peak during the summer time due to higher demand. The price that would be paid by Harvey Cedars will consist of how many kilowatt-hours the facility consumes and the actual maximum demand of kilowatts. Electricity is measured in kilowatt-hours (KWh) of electricity used, and since the site is a commercial facility, the cost of electricity is greater (4). The student's main goal is to determine how much electricity each of the buildings located at the resort needs on average , which will be used to devise methods to reduce the cost of their electricity. In order for the modules to be placed in the correct position, students must take a solar assessment of facility.

This site was assessed by a clinic team of students who took several steps in generating a solar assessment of the resort. This preliminary check determined the best location for the PV system's installation, which will generally be used to determine the total energy that can be generated at the site. Trees should not be cut down in order to eliminate shade nor should buildings be moved to provide a better orientation for modules. An energy audit was also taken by the students in order to account for the energy that each building consumed as part of the facility total, which will factor into the solar assessment results as well (5). Physically viewing the site with careful consideration for large obstruction or fixtures is the first step, which the team must conduct in order to select a possible site where the PV systems can be installed. Since the PV modules are the most efficient when they face true south, locations that face south will be the targeted spots for the modules to be installed. Ideal locations for many panels will be the roof, since that is not only preferred for aesthetics, but also the PV module is more efficient when set at an angle closest to the latitude of the given location.

Harvey Cedars is a hotel resort that has some roofs that stand out to give the resort a modern look, which can cause issues for PV installation. The Chapel building as well as the Victorian hotel have a roof with tiles installed, which give the buildings a beautiful roof texture as well as makes the roof more durable in the long run, but it does not make a good source spot for the PV modules to be installed. Theses tiles can add much weight to the roof since the material that is used is dense and may not be the best area to install the added weight of the PV modules (5). Also these tiles are expensive and are not easy to repair, thus the students determined that the gym, kitchen, and the pool side lodge roofs would be the best sites to take the assessment for the placement of the PV modules. Each of the selected roofs was evaluated for PV installs and students recorded useful information such as roof area and dimensions. Most of the assessed roofs were flat which will require the PV modules to have addition brackets installed; this added to the cost of the system is accounted for in the assessment report. Careful consideration was taken by the students as a warning since these added brackets will also add weight to the PV system, placing added pressure onto the roof. The age of the roof is very important since most modules’ life span is generally around 30 years and the roof may not last that long with the added weight. This was mentioned in the assessment report to the facility to possibly consider replacing the roof before installing any solar PV modules. Inverter location is the next step that is performed, which is important since the price varies based on the distance of the inverter from the system. The further that the inverter is from the PV systems the more cables that will have to be run, and since the resort has no plans on relocating their site, the students will simply explain this cost factor in the assessment report. Students next conducted the portion of the assessment where objects are taken into account that would project shades onto the roof. This is a very important step since the outputted energy can be greatly reduced when the panels are partially shaded. The Solar Pathfinder is the tool that was used at the Harvey Cedars site; this tool is used to determine the tested area’s solar window, which will help show at what time of the day the PV module will be shaded as shown in figure 1 and figure 2.



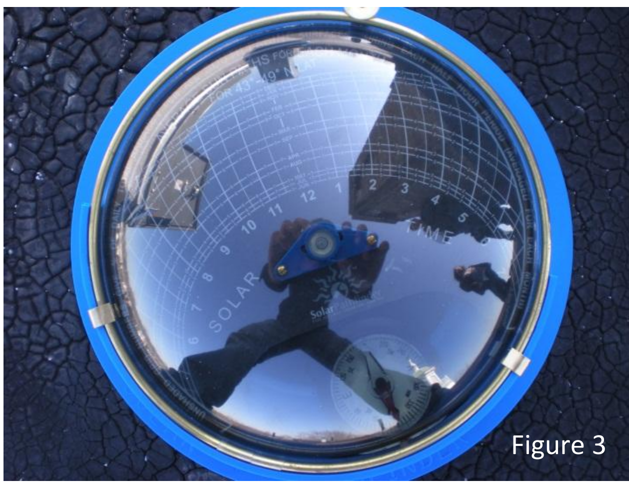
Figures 1 and 2. Solar Pathfinder images taken from a site assessment

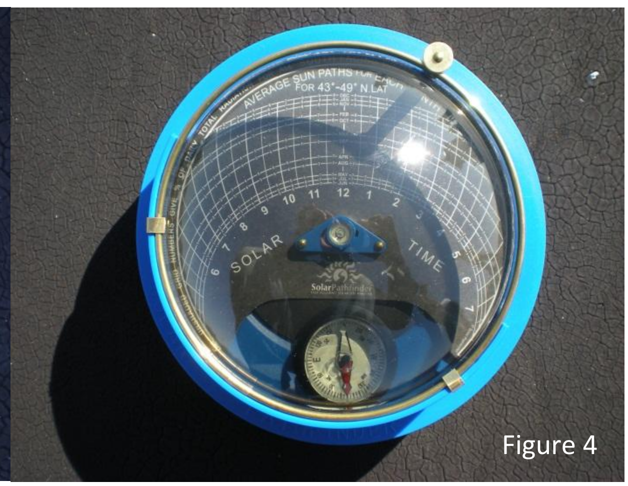
The students set up an array of assessment spots, as shown in Figures 1 & 2 that were assessed and would be consider for PV installation. Any spot that has a solar window less than 90 % is not a spot that should be used, since the panels that are installed will be in series and will greatly affect the overall performance of the PV system. For example, the site in Figure 2 has a 100% solar window and is an ideal location to install a PV module, while the site in Figure 1 has about a 72% solar window. These pictures are uploaded directly into the Solar Pathfinder Assistant

Software and are processed through a program that evaluates the image and gives back composite site survey results [3].

Shpeen Hall

In March 2011, Rowan University decided they consider installing a PV system on Shpeen Hall due to the building being scheduled for a roof replacement. The Clinic team was asked to generate a small PV feasibility analysis. A group of five students conducted the assessment (4 undergrads and 1 grad student). Spheen Hall’s roof had some areas that were very good for a PV system, since one part was south facing and angled at 40 degrees. . Pictures of the solar pathfinder were taken at a matrix of spots where PV modules could be used. Asphalt shingles are very affordable and easy to replace which benefits the PV systems since installation can sometimes cause damage to the roof. If the roof is replaced, the asphalt shingles would be changed at a perfect time since their lifespan ranges from 20-25 years.





Figures 3 and 4. Solar Pathfinder assessment of Shpeen Hall.

The Solar Pathfinder assessment displayed that the roof had some shaded spots that should be avoided for use in a PV system. Once the new roof is installed, some of the obstructions may no longer be in the same spots. Roof access was four stories above the ground which eliminated most of the shading impacts from surrounding trees. Figure 4 showed that in some area of Shpeen Hall had a 100% solar window while in Figure 3 the roof also proved to have some shaded spots around 2 o’clock, which results in an estimated solar window of 62%.

Wind Data Assessment

Students have to possess the skills to organize their given projects and make room to complete a number of different projects at a time within each clinic. This is a skill that is enforced in order to better prepare each student for the high demand that the industry has today, which requires employees to complete multiple projects simultaneously. During the spring semester of 2011, another project that the Rowan University's student Clinic team worked on was assessing wind data from different sites in the order to determine what amount of energy could be possibly generated. As shown in table 1, the wind data that is collected shows the possible generated watts for each site location. The assessment will be used to report whether or not these sites will prove useful to install the wind systems and integrate the system into the grid. The Clinic team analyzed the data and created power curves for each separate turbine model to display the potential power generation of each at the tested site area.

Wind Potential Generation

Total Annual Watts of Possible Generation

Sites→	Ocean Gate, NJ	Bayshore Discovery Project, Port Norris, NJ	SJ Tech Park, Mullica Hill, NJ	Lebak Farms, Chesterfield, NJ
Elevation	30 meters	**50 meters	30 meters	30 meters
Data Range	4/07 to 1/08	11/05 to 11/06	11/10 to 1/11	8/06 to 8/07
Model				
Skipper	671,366	1,011,735	1,238,095	488,025
Morpho	799,613	1,334,875	1,618,410	587,500
Emperor	1,288,859	2,259,320	2,702,635	943,640
Viceroy	3,498,306	5,988,650	6,912,954	2,573,750
Daggerwing	6,502,548	10,941,000	12,672,654	4,833,600
Swallowtail	9,712,913	16,908,650	19,285,578	7,151,000

Table 5

Table 1 is a summary of all four sites that were assessed; each of the site's results were recorded for consideration as possible installation sites. Elevation is important in this assessment since the greater the altitude of the system the more consistent the wind speeds will be. Also the system should generate more energy positioned at a higher altitude since wind speeds increase the higher the system is from the ground [(6)] .There are six different types of wind turbines, which each system has a different maximum wattage range. The model's wattage ranges are as follows: the

Skipper model is a 300W system, the Morpho is a 500W system, the Emperor is a 1kW systems, the Viceroy is a 3kW system and the Daggerwing is a 5kW system.

Future work

Assessment is only the preliminary design in a project. Each of the conducted assessments is a proposed blueprint for a system's design. Each student will continue to work towards giving useful feedback for the clinic classes that will help improve the overall experience.

Lessons Learned

An important lesson that each student learns when conducting these assessments is to adapt to the given area, and not always attempt to change the environment. Students learn to assess the best placement for the system, and issues that may affect the system, such as wind, total roof weight, southerly placement, and avoiding shady areas. These lessons are learned by the students in order to protect the environment by using the tools that already exist and improving on them. Students learned how to perform solar assessments using Solar Pathfinder, PV Watts, as well as work in the current industry gaining useful experience. Also, students analyzed wind data to review potential sites for wind turbine installations.

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