Parking and Street Lighting with Solar and Wind Energy Powered Retrofitted LED Lights

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Abstract

A campus energy education and awareness program has been implemented to help ensure unnecessary building lights are turned off when rooms are unoccupied, and lights that draw major current are being replaced with light emitting diodes (LEDs) at Sam Houston State University (SHSU). Implementation of energy efficient lights such as LEDs will reduce energy consumption in campus parking areas and streets. To support this initiative, a group of students from the technology program (electronics, construction management, design and development, and safety) is involved in a series of energy projects to help energy conservation endeavors on campus. Students did a literature review of current night and security lighting technologies (high pressure sodium, HID-high intensity discharge, mercury vapor, and induction) currently in use in building site lighting at campus parking lots and on streets; they then compiled a summary report to explain inefficiency of the current lighting. Students and faculty proposed an installation of several LED lamps (DC) on pilot locations that are powered by solar modules and wind turbines to determine an efficient (cost, lifetime, illumination capacity) LED technology. This undergraduate research project is one of the campus-wide efforts to promote energy conservation and use of clean renewable energy resources.

Introduction

An LED lighting initiative is a common attempt to reduce the energy consumption on academic campuses. By installing energy-efficient LED lighting technology, colleges can lower energy consumption, decrease maintenance costs, and lessen wear and tear on heating and cooling systems. As one of the least risky sustainability practices with a rapid return on investment of less than three years in many cases, LED lighting also allows colleges to implement projects in phases. LEDs have longer lifespans and lower energy consumption levels than conventional bulbs. A major advantage of an LED is low energy consumption and operation lifetime with no or minor maintenance when compared to traditional lighting, such as HIDs, incandescent, fluorescent, etc. The cost of LED lighting may be an issue when a major retrofit is planned on campuses, but the payback will be around three or four years, depending on capacity of the LED lighting deployed. LED lights are similar to typical light bulbs, with the main difference being that they do not have a filament in them—the reason why they burn for so long. Because LEDs do not use a filament, they also do not get hot, and they run on less electrical power, making them more energy-efficient.

There is a variety of energy projects targeted to reduce energy consumption on campus. For instance, faculty members, students, and staff from Southwestern University (Georgetown, TX), developed a course that focuses on energy conservation strategies for the theater, particularly the replacement of incandescent lighting fixtures with systems that use LEDs. This project initiated an extension of projects on campus, including the physical plant, which considered using LED lights for streetlights and pedestrian lights [1].

Another educational project was awarded to support building renovations at DuPage College. The Illinois Clean Energy Community Foundation awarded a $100,000 grant to support renovations to the Berg Instructional Center, Student Resource Center, and College Center. The funding enables progress toward US Green Building Council LEED Silver Certification that will assure energy-efficient features are incorporated into building design and engineering plans. LEED certification is a nationally recognized benchmark for the design, construction, and operation of high performance green buildings.

Through a $110,000 grant from the Illinois Clean Energy Community Foundation, light emitting diodes (LEDs) will be installed as primary lighting in the buildings' high-profile public areas such as student lounges, snack bars, restrooms, building entries, corridors, and reception areas. LED lighting fixtures will also be installed as supplemental accent lighting in classrooms and conference rooms. Energy savings ranging from $14,000 to $23,000 per year will be realized as the college replaces 1,428 light fixtures with those containing LEDs. Recently, there have been many attempts to incorporate solar power with LED indoor and outdoor lighting due to its low power consumption. Researchers investigated feasibility of such projects, especially focusing on economic feasibility and site assessments [2-6].

The rapid development of efficient high power LEDs has led to the production of a variety of lighting applications, broadening our horizons and giving us different concepts and uses of lighting design. The advantages of LEDs are that they can now compete with, and even surpass, traditional illumination. Furthermore, powerful new legislation demands consideration of the environmental impact of a product over its life cycle, from production to disposal. All of this makes LEDs the ideal candidate for an environmentally friendly light source. According to Tsuei [9], the worsening of the problems regarding global warming has made the development of renewable energy sources the focus of worldwide attention, one of which is solar energy and its applications [7-9].

There have been many energy conservation attempts recently to incorporate LED lighting to decrease power consumption, increase life-span of lights, and to decrease maintenance of lights. The Department of Energy has been supporting LED projects under the program called "Gateway Demonstrations" [10-11]. One of the recent state-wide Gateway Demonstration projects was created for the Jordan Schnitzer Museum of Art, Eugene, OR, in January 2011: the "Demonstration Assessment of Light-Emitting Diode (LED) Retrofit Lamps" [12]. In this project, 90W PAR38 130V narrow flood lamps used for accent lighting were replaced with 12W LED PAR38 replacement lamps for a special exhibition, and the museum also staged a side-by-side comparison of three different LED PAR38 replacement lamps against their standard halogen lamps. The LED system lighting the exhibition showed a lower present value life cycle cost, using 14% of the energy and having a life 10 times longer than the halogen system.

In another similar project under the same program "LED Freezer Case Lighting: Albertsons Grocery" in Eugene, OR [13], upright freezer cases were retrofitted with LED strip-lights combined with occupancy sensors and compared against standard fluorescent lighting on the opposite side of the aisle. Calculated payback periods approached five years from estimated energy and maintenance savings for a typical 5-door case. Another example of similar projects was completed at the Bonneville Power Administration Headquarters in July 2011 [14]. In the building, 15W and 23W reflectorized compact fluorescent (CFL) track lights used to illuminate artwork were replaced with 12W LED lamps. Although the study did not show rapid payback on the LED installation compared to the CFL products, color quality and power quality improved with the LED lamps, and the narrower light distribution of the LED product more effectively concentrated the lumens on the artwork.

Project Planning

One of the energy conservation attempts is an SHSU technology student LED parking and street lighting project that has been active since 2011. Faculty and students in the Industrial Technology program at Sam Houston State University took the initiative to install hybrid solar and wind energy infrastructure and LED lights to join SHSU's energy initiative plan. For this plan, students collaborated with the university physical plant administration to determine problems and needs and then came up with potential solutions. Physical Plant staff regularly audit the work students have been doing with faculty mentors.

The initial project site was one of the satellite campuses where there are six metal buildings averaging 10,000 sq. ft. each. In this location, buildings are illuminated by wall mount traditional lighting. There was insufficient illumination for the buildings, especially for the parking lighting. Most of the buildings in this location are accessible during the evening hours due to night classes and capstone projects. Initially, physical plant officers offered two different spots in this location and provided light poles (for two LED light fixtures), old light fixtures (used for HID lamps), and service (official auditing and approvals, bucket trucks etc.) for installation.

Project Design

Initially, students majoring in Industrial Design and Construction Management were tasked to create a 2-D/3-D model of the project infrastructure. Students worked with project faculty, physical plant administration, and a licensed master electrician to design the infrastructure. The design work is shown in Figures 1 and 2. The infrastructure was located near the 10,000 sq, ft. production laboratory. All of the production, assembly, and testing processes were accomplished in the production lab before implementation. Autodesk Inventor was used to design the complete renewable energy-training infrastructure. After the design process and all the approvals, construction management students and faculty built a powerhouse (12ft X 8ft X 10ft) for all of the equipment. Figure 2 shows the layout of the outdoor wiring and conduits from light poles to powerhouse.

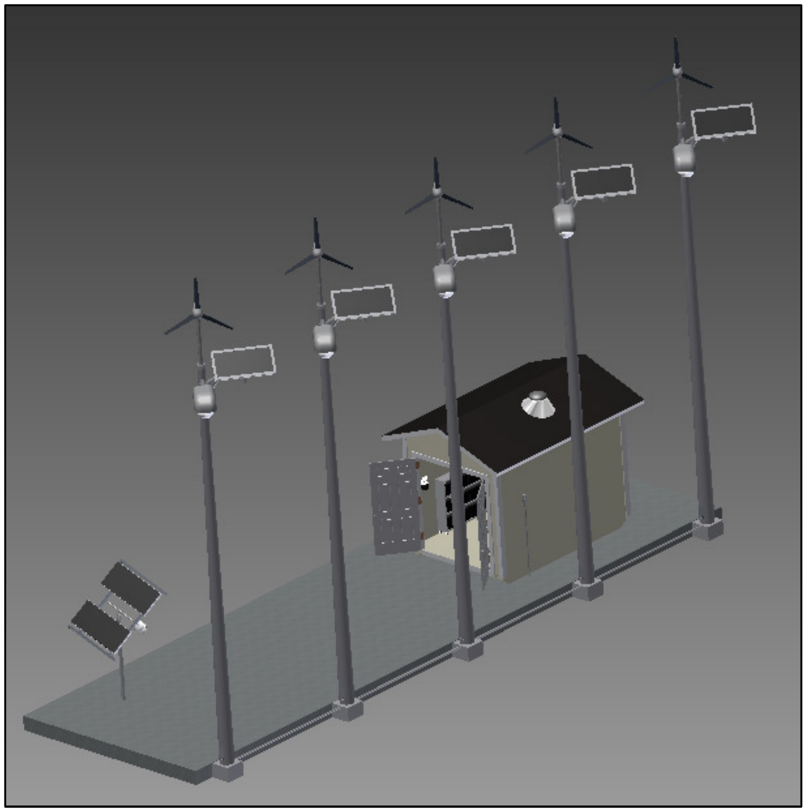

Figure 1. Complete design work for the hybrid solar-wind energy system

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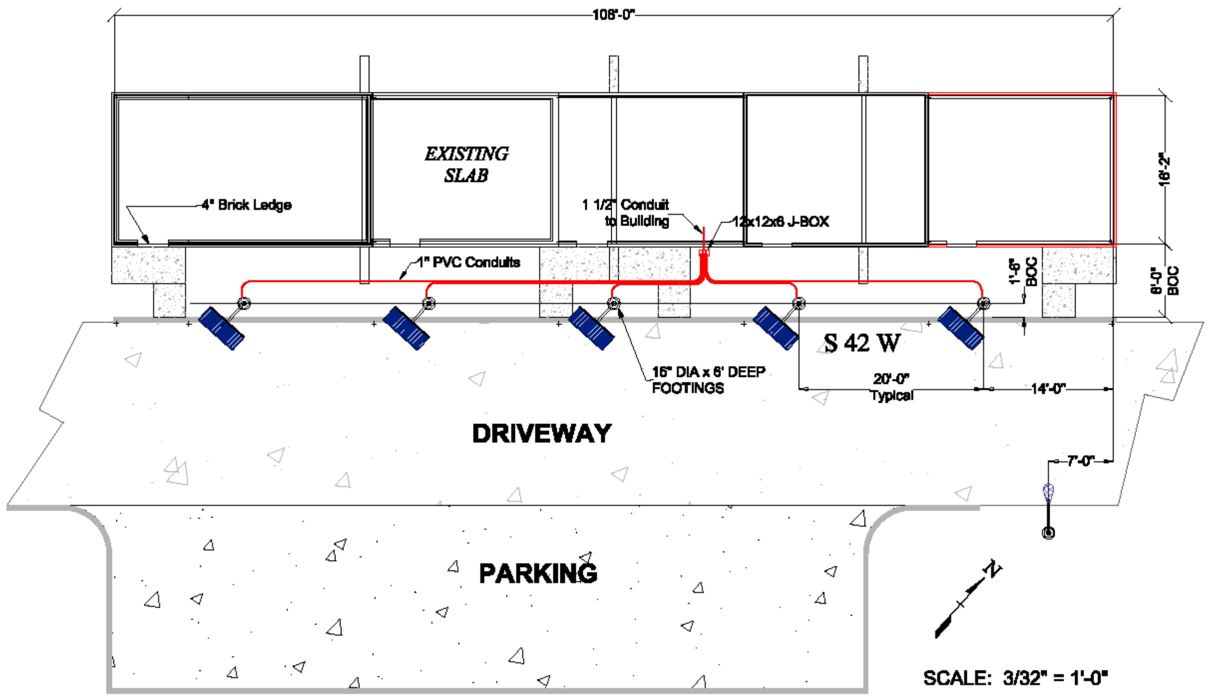

Figure 2. Layout drawing for the location of the light poles, powerhouse, and conduit

Project Implementation

Students built concrete foundations for light pole footings and installed light poles in selected locations. Light poles and light fixtures were retrofitted to install LEDs, solar modules, wind turbines, and battery packs. Students also studied and reported normal operation time for lighting, local average wind speed, local average sun illumination, the load capacity of light poles, and secure location for batteries and controls. Seven light poles were installed near the industrial technology lab facility by construction and electronics major students.

Shading analysis for the solar energy was completed using solar path finder shading analysis tools. For the shading analysis, students were divided in groups and were provided with Solar Pathfinders, assistive software, and laptops [15]. A short description of the equipment summary of the experiment was provided to students. A sun path calculator was used to view the solar window for a particular location for assessing shading. Other means can be used to evaluate shading, but sun path calculators are usually the quickest and easiest to use. The Solar Pathfinder was located at the proposed array site, leveled, and oriented to true south with the built-in compass and bubble level.

After shading analysis, five poles were installed and solar modules, wind turbines, and LED light fixtures were mounted. The design work of brackets and metal frames to mount wind turbines, solar modules, and LED light fixtures to properly and securely attach the power generation components was completed by design and development students. All the brackets and frames were built and tested in the lab facility. Figure 3 shows pictures of the light poles with the wind turbines, solar modules, and powerhouse.

Figure 3. Solar photovoltaic and wind project environment

Additionally, old light fixtures were retrofitted and rebuilt to house new LED lights to be attached to light poles. Students were able to fit two or three efficient LED lights into a single light fixture for future studies. A comparison study between various LED lights and traditional street/parking lights was conducted and reported to the university physical plant. Figure 4 shows LED light fixtures (day and night).

Students and faculty members worked on the integration of the system components and wiring to complete the project. A bucket truck was provided by the SHSU Physical Plant to install the solar panels, LED light fixtures, wireless weather station, and to pull the wires from light poles to powerhouse. Students were provided experience in various types of job duties, such as determining right conduit sizes, installing conduits, pouring concrete slabs for the light poles, learning wire types and codes, calculation wire gauges, balance of the components of the solar PV system, dealing with AC vs. DC electricity and conversion, deep cycle batteries, various power tools, preparing and reading electrical and construction drawings, finding correct location and tilt angles of the solar panels, etc.






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Figure 4. Retrofitted light pole housing, battery and controller boxes, LED light fixtures

Following are the learning outcomes of the project:

- Brainstorming sessions
- Meetings with physical plant staff
- Site analysis
- Proposal writing for funding and permissions
- Purchasing
    - Cost analysis
    - Contacting companies
- Implementation
    - Design (2-D/3-D)
        - AutoCAD
        - Autodesk Inventor
        - PTC Pro Engineer
        - Microsoft Visio
        - AutoCAD Electrical
    - Construction
        - Powerhouse
        - Running conduit and wires
        - Tower installations (light poles)
- Team Work
    - Construction management, electronics, design and development, safety

- Testing the overall system
- Publications and reports

In terms of student learning and satisfaction, the project was a success. With the increasing importance of energy conservation and clean energy resources in present and future energy scenarios, an ability to design and analyze renewable energy systems becomes essential for engineering and technology educators and students. All students in the project showed improvement in learning and understanding concepts of energy conservation through both the project and the complementary theory-based lecture with hands-on experiments. We are hoping to increase the number of experimental projects and to cover additional renewable sources that complement even more of what was covered previously.

The hands-on experience from the projects provided the students with the opportunity to demonstrate the knowledge that they have gained in previous projects. Students learned about various aspects of energy conservation including problem identification, technical, social and environmental constraints, multidisciplinary team management, communications and documentation skills. This project also provided the students with an opportunity to view their designs from an ethical and sustainability awareness perspective, thus realizing a lifelong learning opportunity. Through practice, the students realized that the key success to a design project is teamwork, industry interaction, and collaboration.

Conclusion

This project was mainly accomplished by students and is very supportive of campus-wide efforts to promote energy conservation and use of clean renewable energy resources. The university physical plant decided to hire two of the students who were involved in the renewable energy projects to do campus wide energy assessment. This and similar projects have been done on campus and demonstrate the viability of renewable energy to reduce the amount of money the university pays to the utility company as well as reduce harmful gases that speed up global warming. Student feedback has been very positive in terms of learning outcomes gained from this project. Students asked to be involved in more campus-wide projects and asked to extend this project to local community for energy assessments. Two of the students requested small funding to prepare and mail brochures/flyers about LED lighting and energy conservations.

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Biography

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