Work in progress: Energy Sustainability for First-Year Engineering Students-Exploring Renewable Energy Production through Hands-on Activities

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ABSTRACT

This work-in-progress (WIP) manuscript aims to introduce hands-on experimental projects focused on energy sustainability for first-year engineering students. It is based on project-based, experiential learning (PBL) criteria. PBL is proven to nurture learning via practical projects, promoting collaboration, communication, safety consciousness, and critical thinking. Guidelines of the Accreditation Board for Engineering and Technology (ABET) and the High-Quality Problem-Based Learning Organization (HQPBL), which include, but are not limited to: "Intellectual Challenges and Accomplishments", "Authenticity", "Public Product", "Collaboration", "Project Management", and "Reflection" are followed. For this manuscript, our primary focus lies on "Authenticity", which emphasizes the significance of PBL projects that generate tangible benefits for individuals and communities beyond the educational environments of classroom and school. Our objective is to fulfill all necessary ABET criteria, while acquainting students with the benefits and drawbacks of wind, geothermal, and solar energy production through hands-on projects.

INTRODUCTION AND BACKGROUND

PBL, which originated from McMaster University in 1965, involves hands-on projects guided by instructors, promoting exploration and knowledge acquisition. PBL stems from constructivism, and contrasts with traditional lecture-based methods by actively engaging students in the learning process through structured, practical experiments. The essential PBL criteria based on HQPBL include: intellectual challenges, authenticity, public product, collaboration, project management, and reflection. Studies have shown various implementations of PBL, highlighting its benefits in enhancing student engagement and skills, particularly in addressing real-world problems and fostering critical thinking, collaboration, and problem-solving. Examples include projects on water sustainability, carbon footprinting, and wind energy, demonstrating PBL's effectiveness in integrating sustainability into engineering education [1-17]. This manuscript focuses on the authenticity aspect of PBL and presents multiple sustainability-focused PBL experiences.

EXPERIMENTAL PBL PROJECTS FOCUSED ON SUSTAINABILITY

At the time of preparing this manuscript, three projects focused on sustainable energy production/utilization (wind, solar, and geothermal) are currently in the design phase. The following subsections provide more information about these projects.

WIND ENERGY PRODUCTION

The overall objective of this project is to design, build, and test a wind turbine. The wind turbine is utilized to study the impact of variables such as wind speed and turbine blade length on generation of electricity. This project is inspired by a KidWind project [18].

Teams are provided with PVC pipes to build a tower and base for a wind turbine. A DC motor fitted into a PVC elbow is rotated by the turbine blades. Each team also receives a fan with variable speed to simulate wind. Turbine blades are made from cardboard in two lengths. A schematic image is shown in Figure 1.

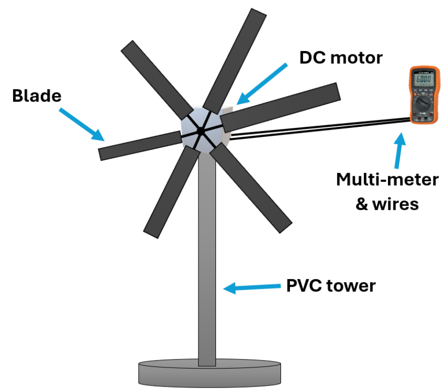

Figure 1: Schematic of the wind turbine

The generated power is measured using a multi-meter which records the output voltage and amperage for each fan speed and each set of turbine blades. To correlate the generated power to the wind speed, an anemometer is used for measurement of wind speed. Wind power at each fan velocity is approximated using equation 1.

$$P = \frac{1}{2}\rho_a A v^3 \quad (1)$$

Where, "P" is power (watts), "ρ_a" is air density (kg/m^3), "A" is the air flow area (m^2), and "v" is air velocity measured by the anemometer (m/s).

The calculated wind power is then compared against the power generated by the turbine at different fan speeds and blade designs and the efficiency of power conversion is calculated for each combination, which helps in selection of the best design.

SOLAR ENERGY UTILIZATION

For solar energy utilization, student teams are to build a system for measurement of energy output of a solar panel at different times during the day. It is made of a box with a variable aperture (Figure 2).

Students use an aperture to control radiation entering the box (a solar oven), mimicking sunlight variations throughout the day. They aim to optimize voltage and amperage output of a solar panel by adjusting the aperture and modifying the oven's design. Experiments are conducted indoors using a lamp to simulate sunlight. Teams must adhere to specific dimensions and aperture settings for consistent testing. Voltage and amperage readings are recorded for different aperture sizes, and results are plotted against an equivalent "time of day". Following the engineering design cycle, students analyze their findings, discuss design success or failure, and propose improvements. After adjustments, experiments are repeated for comparison.

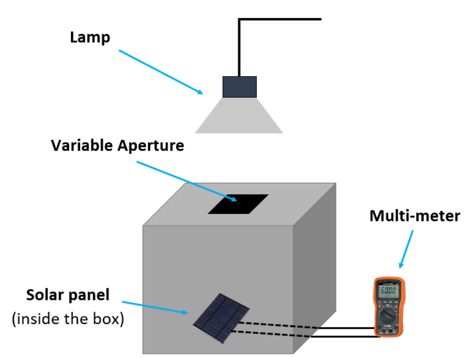

Figure 2: Solar energy conversion setup

GEOTHERMAL ENERGY PRODUCTION

A double-pipe heat exchanger (DPHE) project (Figure 3a) is adapted for geothermal energy production. The setup simulates the transfer of heat from hot underground rocks to cold surface fluids (in this case, water). Teams use thermometers to monitor temperatures of hot and cold sources. Multi-meters are used to measure the voltage and amperage of a thermoelectric generator module (Figure 3b) before exposure to hot and cold sources and after exposure, over time. Student teams then calculate the generator's output power over time and create plots of temperature difference and power vs. time for analysis.

(a)

(b)

Figure 3: a) Double-pipe Heat Exchanger setup, b) Thermoelectric Generator Demonstrator [19]

CONCLUSIONS AND FUTURE WORK

This manuscript outlines three projects centered on sustainable energy production for first-year engineering educational purposes. The projects cover wind, solar, and geothermal energy production. Each project begins with a problem statement including safety guidelines and learning objectives, followed by team formation and role delineation. The manuscript provides a brief introduction to each project, from equipment requirements to experimental procedures.

Currently, all projects are undergoing the design phase. Next steps involve purchasing all necessary equipment, constructing prototypes, and conducting tests to validate the underlying assumptions for each project. Subsequently, based on the average size of a first-year class, we will acquire the required equipment to ensure readiness for use.

Pre- and post-project ABET-based surveys will be assigned to students for each project. This is to gauge their understanding of each specific subject, as well as potential improvements in their self-efficacy and sense of collaboration in teams.

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