

# An Evaluation of Microgrid Design Projects Integrated in a Pre-College Summer Program

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**Abstract** – The integration of real life design problems was the anchor of a pre-college summer program. This paper describes the secondary education level student project that involves the conceptual design of standalone distributed generation system microgrid as a solution to the future power grid design for Hampton University (HU). A discussion and evaluation of fifteen design solutions that were produced by three cohorts of high school students from the summer of 2011-2013 will be covered. Solutions were to consider both the engineering challenges and the economic impact in both upfront cost and long term return on investment. The student team presentations were evaluated based on the technical design content, creativeness, teamwork, and display of professional skills. The conceptual design solution required the considerations of renewable energy resources and the elements of cost effectiveness, energy efficiency, and environmental impacts for the Hampton Roads region of Virginia. The evaluations from the expert panel of judges showed that the depth of understanding of the proposed solutions over the three year period indicated continuous creative thinking amongst the age group of first and second year high school students.

*Keywords:* Pre-college program, STEM education, project based learning.

## BACKGROUND

There is currently a favorable local and global interest in integrated STEM education in pre-college programs especially as a way to provide students problem solving skills necessary to succeed in fields such as engineering. The keys to integrating STEM education involve concepts such as problem-based learning where the students are involved in defining and optimizing solutions to practical real life problems. The delivery of knowledge encompasses making practical connections with the problem, performing research, bridging the researched knowledge with the problem at hand, and applying a solution to the problem, and then effectively communicating the solution [1][2]. In this context, a two-week summer program for mainly rising 10th grade students was established at Hampton University with the following objectives: (1) to demonstrate interdependence of engineering and business in making real world choices; (2) to introduce engineering methodology as a means of problem solving; (3) to expose students to the entertaining, yet challenging world of engineering; (4) to introduce students to cutting edge, computer-aided design software used to solve day-to-day problems; and (5) to develop teamwork skills. The program engages students in problem solving, and hands-on experience through design contests, engineering case studies, and educational field trips. This paper reports on the engineering Case Study that students experience for 2 weeks in parallel with other activities. The culmination of the two-week program is the presentation of the Case Study solution before an audience that includes parents and business and engineering professionals.

## MICROGRID DESIGN PROJECT

During the *Case Study activity*, students were challenged to design a conceptual future energy grid that is most conducive for the Hampton University campus. Students worked in teams and were expected to present their

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solutions that integrate energy systems with the consideration of technical, economic, and environmental factors, among others concerns, in making solution recommendations. The students were also expected to apply content knowledge gained from various workshop sessions offered during the program. Each case was to be a conceptual model based on the knowledge gained from doing the modules on different energy systems such as:

- Wind turbines and wind powered boats
- Solar cells and solar powered homes
- Customized community grids (Electrocity™ [1], microgrids)
- Field trips to relevant energy and engineering business and laboratories, etc

### Case Study Project

Objectives of the Case Study included:

- Learning engineering approaches associated with design power/energy systems.
- Learning usage of computer tools in the design and analysis process.
- Planning design of energy delivery systems using Computer-Aided Design (CAD) tools.
- Learning prototyping energy systems.

Outcomes of the case project were to be a:

- Determination of electrical energy generation capacity
- Determination of energy resources suited for the campus of Hampton University; to include current and future energy demands
- Determination of the cost for building the future energy grid for the Hampton University campus.
- Determination of the future energy grid's environmental impacts
- Conceptual design for a grid-independent smart grid for Hampton University

### Case Study Presentation

A final presentation of the Case Study solution was to include the following:

- Engineering Problem Posed
- Conceptual Design Solution
- Mathematical/Cost Analysis
- Engineering Decisions/Comments
- Business Decisions/Comments

The conceptual design solution required presenting all of the considerations of renewable energy resources and the elements of cost effectiveness, energy efficiency, and environmental impacts for the Hampton Roads region of Virginia and was evaluated based on the rubric shown on Table 1.

## PROJECT DEVELOPMENT

The project was developed such that components of project-based learning were integrated. Therefore, the project development process included components on project reflection, research, discovery, application, and communication that were highlighted in activities undertaken in student preparation for the microgrid Case Study.

**Case Study and Renewable Energy Projects:** Over the two week period, the teams were given the task of creating a proposal to develop an alternative power system design for the future for Hampton University that was conducive to the campus' size and surrounding areas and not dependent on the existing power utility company. The students had to take into consideration the population of the campus (faculty, administration, students etc.), building facilities, environmental effects, and the final cost of their designs. Prior to completing this task there were activities that explored different energy resources, power generation, and distribution. A brief discussion was led by a campus power engineer to introduce the students to the current infrastructure of the campus power distribution. In addition, several concepts were explored using design software and hands-on energy kits to simulate energy usage. Desktop wind turbine and solar cell kits were used to explore concepts on wind and solar energy.

The students were first tasked with using an online gaming simulator to build an energy efficient city by balancing population, energy supply (renewable and non-renewable), and environmental impacts. The goals were for the

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students to make decisions while acting as city mayors and were evaluated on their city's population size, popularity rating, sufficient power supply, and minimal environment effect. In order to help the students expand their knowledge about wind energy, the teams were assigned a short project to investigate the effects of blade size, blade pitch (varying from 0 to 60 degrees), and blade type to determine the best configuration for the power output of the wind turbine. For the solar energy mini project, the teams had to investigate the effects of heat, tilt (or angle of the solar panel with respect to the light source), and shade on the power output of the solar panel. Additionally, the students used the home energy simulator, to simulate the powering of a residential house using grid-power only and then with solar power. The simulation allowed them to choose which appliances and lights which could be turned on and for how long and also set the weather conditions to simulate a particular season. This led them to observe the impact of alternative energy and also witness loading effects to see how lifestyle changes (for example, spending only 2 hours instead of 5 hours playing video games) could impact energy conservation. They were able to choose a set of activities that would typically be completed on any given day and the day could happen during any season. The energy cost and energy savings due to solar panel usage were the focus of the activity.

**Other Activities:** Other projects aimed to develop non-technical skills included business communication activities, PowerPoint presentations, team debriefings, icebreakers, college planning/goal setting, and competitive team activities. Prior to each activity, a facilitator provided an explanation of the purpose of the activity. As stated by many of the participants, these activities often required students to perform outside of their comfort zone. For example, many of the icebreakers required students to solve problems as a team within short periods of time. These activities were interwoven with the technical projects to create variety throughout each day. Students were also able to interact with industry professionals in a work setting such as presenting at trade show or touring a light manufacturing facility. Student interaction with industry professionals provides an early engagement of the value and utility of STEM activities in making future educational and career choices.

## PROJECT EVALUATION AND RESULTS

Table 1: The Evaluation Rubric

Evaluation Category	Evaluation Guidelines	Points
<b>Content:</b>	Utilization of a variety of resources and well-informed of subject matter. Evidence of research; knowledge of information; addresses engineering and business concerns; addresses professions needed to implement the project	30
<b>Presentation Skills:</b>	Logical and organized presentation of information, spelling, grammar, visual aids, professional oral skills (eye contact, voice projection, language, etc)	20
<b>Creativeness:</b>	Creativity/innovation (apparent consideration of possible and creative solutions and alternatives), problem solving, practical solution, relevance	20
<b>Teamwork:</b>	Balanced presentation and equally shared amongst team members. Evidence of collaboration, shared talking time, knowledge in answering questions, ease of transitions.	20
<b>Timeliness:</b>	Conscientious about time limits, presentation time, question and answer period, number of slides and usage of slides.	10
<b>Total</b>		100

The basis for evaluation of student team presentations are technical design content, creativeness, teamwork, and display of professional skills as tabulated on the rubric in Table 1 and are in-line with technology and engineering framework literacy expectations [2]. The technical content included the understanding of the engineering problem statements, conceptual design, cost/economic analysis, and the balance of business and engineering decision-

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making. Project evaluations occurred through active interaction between students and industry professionals (business and engineering) from Battelle, an applied research and science non-profit company. The student presentation of the Case Study to industry professionals (serving as Judging Officials) culminates in a question and answer session. Questions cover a range of focus areas such as the rationale for design selections; environmental impact and return on investment.

The following summary observations are the result of interviews with Business and Engineering professionals involved in the program over the course of the past three years. First, student projects have evolved over the course of the past three years. Students are capable of increasingly more complex trade-off analysis between meeting operational requirements for a viable microgrid and a sound business decision regarding the impact to the environment and return on investment. A key element of this is providing students with increasingly advanced tools and simulators to help build their project. Second, students clearly demonstrate a high degree of teamwork and leadership. All teams over each of the three years demonstrate the ability to establish a work team built around structured activities. In all instances, a natural leader has emerged and all team members understand the need to respect each other even when there are differing opinions about design selections revealed during question and answer sessions. Third, students engaged as peers to industry professionals interacting accordingly. Students quickly learned during their project evaluation to engage judges as equals. They clearly understand the value of scientific reasoning and engineering rigor as a foundation to engage the judges about their decisions from a position of strength. They demonstrated a high degree of confidence and willingness to engage complex questions posed by the judges. Finally, students actively engaged industry professionals upon the conclusion of judging activities to seek more information about engineering, scientific and technology based careers.

The Case Study activities in the *Business of Engineering summer pre-college program* serves as a catalyst for early engagement on the value of STEM skills. The program encourages students to think outside the box using STEM based activities infused with business and leadership development principles. The Case Study was a culmination of each activity and skill introduced throughout the course of the program. The students needed to utilize both the financial and presentation skills from a business standpoint and technical skills for innovative solutions with practical implementation possibilities.

In three years, solar energy solutions have featured in 73% of the student microgrids and the best evaluated solutions featured biomass, solar, and wind for 2011; wind and solar for 2012; and biomass in 2013 as summarized in Table 2.

Table 2: Student Microgrid Energy Generation Solutions (\*Judged Best Solutions)

	<b>2011</b>	<b>2012</b>	<b>2013</b>
<b>Team 1</b>	Nuclear, Solar, and Hydroelectric	Hydroelectric, Lightning, Solar, and Geothermal	Wind and Solar
<b>Team 2</b>	Solar and Nuclear	Hydroelectric	Biomass, Solar, and Wind
<b>Team 3</b>	Solar and Hydroelectric	Solar and Wind	Nuclear and Solar
<b>Team 4</b>	Diesel Generators	Solar and Geothermal	Wind and Natural Gas
<b>Team 5</b>	<i>Biomass, Solar, and Wind*</i>	<i>Wind and Solar*</i>	<i>Biomass*</i>

A review of the best team’s presentations over the past three years shows a steady improvement in melding both business and engineering principals. The results show that the process of project based engineering was better understood and presented by the instructors, and better utilized by the students. While the cohort of students was different each year, it was possible to see that the instructors had taken lessons learned to heart and helped the successive groups better understand the business of engineering.

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In 2011, the team (team 5 on Table 2) with the best presentation provided an innovative and generally environmentally friendly solution. While they demonstrated they understood the relationships between people, costs, the environment, and engineering, they did not tie everything together in a problem-solution-return on investment (ROI) structure. They also did not consider the environmental impact of a biomass generator on a storm vulnerable campus and in addition, they suggested a site located on the beach.

The 2012 best presentation showed significant improvement over the previous year. The team presented the economic considerations up front and made considerations for alternative sources of revenue such as producing extra power to sell to the utility companies. They reviewed both pros and cons to their potential approach including improvements to the existing campus electricity grid. There was a good balance of people, cost, environmental impacts and concerns, energy demands and supply, and engineering. They also made good use of references to bolster their conclusions. However, they did not establish how much space will be needed for wind and solar panels.

The 2013 best team, started off by immediately linking the problem and potential solutions, to the costs, engineering challenges, business and people needs, and return on investment. They provided an in-depth analysis of the resources needed to implement their proposed solution. Like the best team from 2011, they choose biomass, but picked a site off campus and away from the coast. They considered the trade-offs of various approaches and used several references to support their decisions. Perhaps the biggest leap from previous years is that they showed the return on investment and potential profit once construction loans were repaid.

In reviewing the growth of the microgrid Case Studies offered in the Business of Engineering pre-college summer program over the past three years, a tangible improvement can be seen in each successive year. The instructors have been able to adjust their project based approach to ensure that both business and engineering are represented and linked. External judging has helped eliminate potential bias because the judges perform their evaluation without any prior knowledge on the teams or their particular solutions. As a result, the evaluations were solely based on how well the teams communicated their solutions based on the evaluation criteria presented in Table 1. The consensus on all the winning solutions over the three years hinged on the creativeness and practicality of implementing the solution, and the 2013 winning team presented the most comprehensive response of all three project years.

### CONCLUSION

Proponents of project-based learning (PBL) cite numerous benefits to the implementation of the approach in the classroom settings including a greater depth of understanding of concepts, broader knowledge base, improved communication and interpersonal/social skills, enhanced leadership skills, increased creativity, and improved writing skills [4][5]. The microgrid project and the smaller projects designed to support the microgrid project exemplified the benefits of problem-based learning. The evaluation of the student projects by professionals demonstrated student understanding of microgrid design content through creativeness and teamwork, which was displayed in professional presentations. The projects illustrated the students' understanding of engineering and business tradeoffs as well as environmental impacts associated with renewable energy generation solutions.

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