# Promoting Energy Awareness through Student Projects in Renewable Energy

**by**

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**Abstract:** *To address the growing need for renewable energy education, student projects in renewable energy have been developed and delivered as an integral part of an introductory thermal science course in a mechanical engineering technology curriculum. Projects involve student research in renewable energy, development and testing of an energy conversion apparatus, and an economic analysis. Recent delivery of these projects has included an expanded evaluation tool for the assessment of the impact on student awareness of energy needs and renewable energy solutions. Projects such as these address a gap in current energy education, and can help prepare the workforce to effectively contribute to the emerging energy solutions of the future.*

## I. NEED FOR ENERGY EDUCATION

Motivated by energy security requirements and the desire to create a sustainable and safe environment, there is a growing need to transition gradually from fossil fuels to emerging and renewable energy sources. The Energy Information Administration predicts that U.S. energy consumption will increase at a rate of 1.1 percent annually, but that U.S. energy production will only increase at a rate of 0.9 percent annually, from now through 2030 [1]. These projections are based in part on current usage of renewable energy sources. To narrow the gap between consumption and production, additional usage of energy sources other than fossil fuels is required. Moving toward addressing energy needs of the future is supported by the U.S. Energy Policy Act of 2005, a long-term energy strategy that includes provisions for diversifying energy supplies, increasing residential and industrial energy efficiency and conservation, developing more efficient motor vehicles, improving the electric power infrastructure, and expanding reserve storage of petroleum [2].

An important component of the transition to future energy sources will involve public understanding and acceptance of new and emerging energy technologies as safe and reliable sources for transportation fuels, energy storage, and power generation. People at all levels must be educated about the need for new energy technologies, the uses for these technologies, and their role in the energy solutions of the future. In addition, it will be imperative to create a highly educated workforce who can contribute to overcoming future energy challenges. One method of supporting workforce development in future energy solutions is to incorporate new and emerging energy technology directly into required undergraduate coursework. The Department of Energy's Assistant Secretary for Energy Efficiency and Renewable Energy, David K. Garman, summed up the need for energy education, specifically in hydrogen and fuel cells, when he said,

> *"Investing in our students today will insure the transformation of our energy future from one dependent on foreign petroleum to one that utilizes the most abundant element in the universe – hydrogen," and "It is important that we begin to prepare and inspire the next generation of scientists and engineers who will lead the transition to a hydrogen-based economy and build hydrogen fuel cell powered cars."* [3]

Certainly the same can be said for other emerging alternative energy sources, not just for hydrogen. Engineering and technology educators must develop new curriculum solutions in advanced energy technologies to fill the gaps in existing coursework and prepare the next generation of students to support global sustainability [4].

## II. STUDENT PROJECTS IN RENEWABLE ENERGY

In Fall 2004, ongoing semester-long student projects in the lab-based introductory thermal science course in the Mechanical Engineering Technology (MET) program at Purdue University were modified to require a focus on renewable energy, in an effort to address the emerging topics in energy and sustainability discussed above. Students choose to study one of the renewable areas defined by the Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) [5], including solar, wind, hydropower, geothermal, biomass, and hydrogen. The primary goal of the projects is to provide students with a deeper understanding of the need for renewable energy sources, the advantages and disadvantages of a particular energy type, and the global and economic impact of the chosen energy type. The renewable energy-focused projects, discussed in detail and with respect to ABET program criteria in [6], have been delivered for five semesters and continue on an ongoing basis. An overview of the projects is provided again here for reference (see [6] for additional details).

At the introduction of the project assignment, students briefly investigate multiple renewable energy sources to determine their focus area. For the duration of the project, students complete three major parts for their chosen energy source: (1) research on the history and implementation, (2) development of an experimental application to an energy conversion process, and (3) an economic analysis. First, students investigate the background of their chosen energy type, producing a summary of the history, real and specific examples of implemented systems, insight into political or legislative issues, discussion of the environmental impact, and advantages and disadvantages of the chosen energy type. The second component of the project requires students to design and build an apparatus that converts the chosen energy source to useful energy output, typically electrical or mechanical work. An experiment must also be created and performed to determine the energy conversion efficiency of the system built. Finally, students complete an economic analysis of the chosen energy type, either based on their actual experimental apparatus or on an assumed residential or commercial application. The economic analysis must quantify all initial and recurring costs over an assumed product lifespan, and must present a resulting estimate of cost per kilowatt-hour or similar final economic quantity.

The project assignment is introduced early in the semester and delivered primarily in the laboratory portion of the course. The approximate project schedule, including deliverables, is shown in Table 1. Five deliverables are distributed throughout the semester. In the proposal, students choose a renewable energy source to study and brainstorm possibilities for an experimental apparatus using the chosen energy source. A few weeks later, students identify parts and instrumentation needed to implement their experiment and submit a purchase request (budget = $50 department funds per project group, but unlimited personal spending if desired). The two status reports and the final report include both written and presentation components, although the status report presentations are quite brief.

**Table 1.** Approximate project schedule and deliverables.

| WEEK | PROJECT ACTIVITY |
|---|---|
| **3** | Introduction to Project |
| **4** | Due: *Deliverable 1 – Proposal* |
| **6** | Project Time in Lab |
| **7** | Due: *Deliverable 2 – Purchase Request* |
| **9** | Project Time in Lab |
| **11** | Due: *Deliverable 3 – Status Report I*<br>Project Time in Lab |
| **13** | Due: *Deliverable 4 – Status Report II*<br>Project Time in Lab |
| **15** | Due: *Deliverable 5 – Final Report*<br>Group Presentations |

Projects are completed by student teams, typically in groups of 3 or 4 students. Deliverable grades and the final project grade are assigned as single grade values for the entire project group. At the end of the project, students complete peer evaluations assessing the relative contributions of each team member, which are used to produce an individual weighting factor for the final project grade. The weighting due to peer evaluations is limited to plus or minus ten percent of the group grade.

One of the most challenging aspects of the projects for the students is determining their own measurement and analysis procedures, when much of their laboratory work up to this point in their academic program has been completed by following detailed procedures provided to them by an instructor and/or a lab manual. Therefore, much of the instruction for the experimental part of the project is aimed at ensuring students' efficiency results are computed from energy input and output values, using consistent energy or power units. Students often struggle with making the leap from something they can easily measure, such as water flow rate input for a hydroelectric generator, to an energy or power quantity that can be used to compute conversion efficiency, but they also seem to learn a lot about efficiency in the process.

A selection of example student-built projects is shown in Figure 1. Students primarily choose projects in solar, wind, and hydroelectric energy systems, but a small number each semester choose to study geothermal, biomass, or hydrogen systems. As seen here, the conversion devices built by the students are often small, producing only enough output to turn a small motor or illuminate a few LEDs.

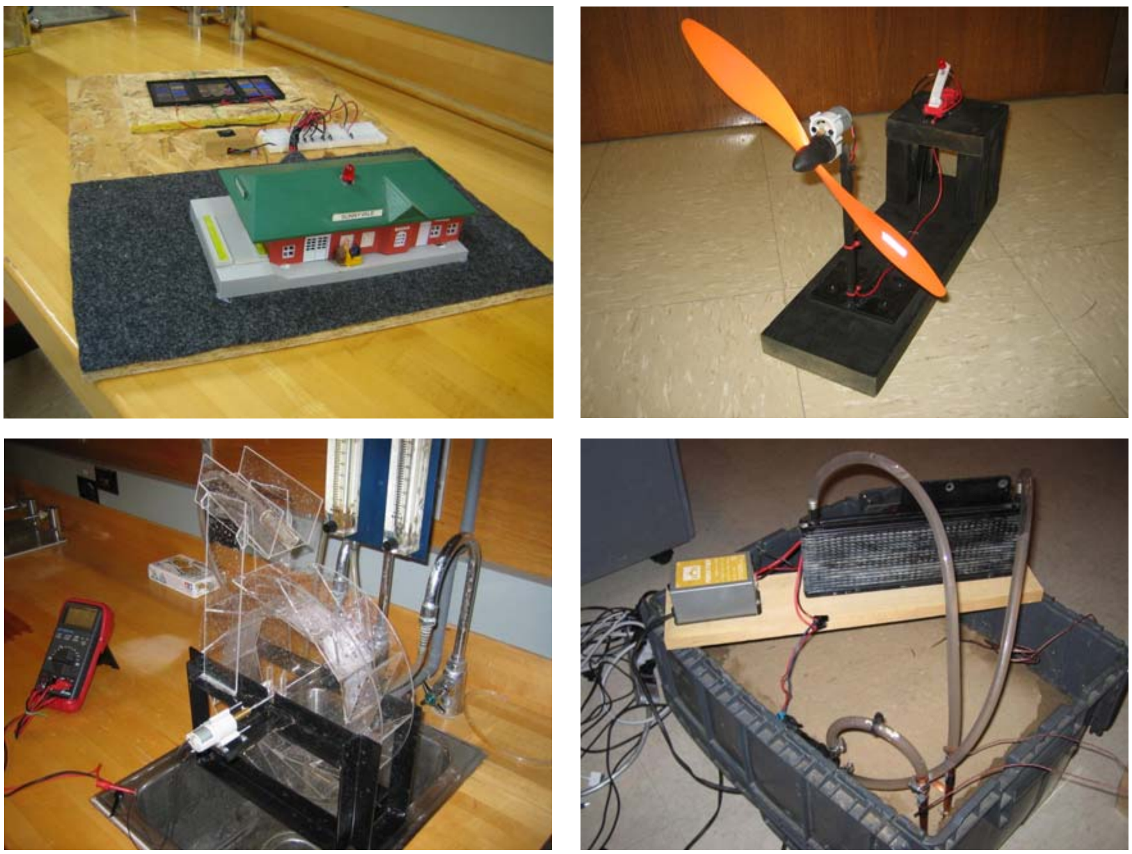

**Figure 1**. Selected student projects in solar, wind, hydroelectric, and geothermal energy.

Energy conversion efficiencies measured by the students are typically low, although actual results vary as a function of renewable energy source and the quality of the students' designs. Figure 2 shows that the majority of student projects in the Spring 2005 semester, regardless of the chosen energy source, were less than ten percent efficient in converting the renewable energy source to useful output energy. Students learn very quickly that it is difficult to achieve highly efficient energy conversion with small, $50 systems. In addition, students often discover that their initial apparatus designs don't always function as expected and learn through failure or trial-and-error. For example, many groups who choose hydropower simply select and purchase a motor or generator for the electrical output without considering if their water supply will produce enough torque to spin the shaft or enough rotational speed to produce significant electricity.

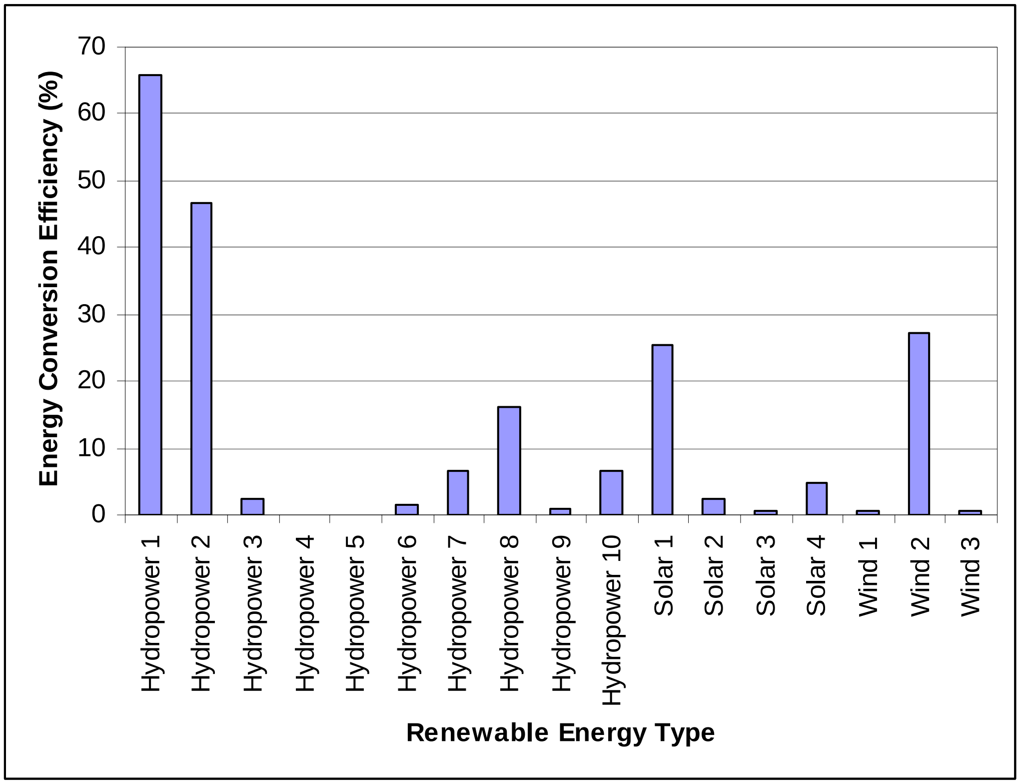


**Figure 2.** Maximum energy conversion efficiencies for student projects in Spring 2005.

Student surveys have been delivered at the end of each offering of the renewable energy projects, demonstrating initial success in increasing student understanding of renewable energy sources and their significance for the future [6]. More than 95 percent of students every semester have reported that the project met the goal of providing them with a deeper understanding of renewable energy and its importance. However, student perception surveys alone do not demonstrate that the renewable energy projects as delivered will help contribute to the energy education needs discussed earlier. In the Spring 2006 semester, an expanded assessment was implemented to further evaluate the impact and effectiveness of the projects. The following sections discuss the updated evaluation tool and initial results from its implementation.

## III. DESIGN OF PROJECT EVALUATION TOOL

In the Spring 2006 semester, the new evaluation tool included a pre-project quiz on general energy topics, as well as a more detailed post-project survey, neither of which was attached to a numerical grade. The pre-project quiz was aimed at overall energy awareness of the students prior to beginning the project assignment. It was expected that many of the pre-test questions, outlined in Table 2, would be difficult for students. In fact, students generally reported that they didn’t know many of the answers, especially the global levels of oil consumption and carbon dioxide emissions. Therefore, the quiz was intended to open students’ eyes to some energy-related issues and set the stage for the upcoming renewable energy projects. In addition, after completion of this quiz at the beginning of the project, it was stressed to students that the answers to these questions could be obtained through the investigation of renewable energy as part of their project assignment.

**Table 2.** Pre-project quiz question topics in the Spring 2006 evaluation.

| | |
|---|---|
| **1** | Current global level of consumption of oil (petroleum) for energy production *(multiple choice)* |
| **2** | Current global level of carbon dioxide emissions from usage of fossil fuels *(multiple choice)* |
| **3** | Rank of energy sources based on their relative contribution to pollution levels *(rank five options)* |
| **4** | Top three renewable energy sources currently used for U.S. energy production *(circle three of six)* |
| **5** | Current cost of electricity, oil, and hydroelectric energy *(fill in the blank)* |
| **6** | One advantage and one disadvantage of using renewable energy sources *(short answer)* |
| **7** | Biggest barrier to increasing worldwide usage of renewable energy sources *(short answer)* |

The post-project survey, outlined in Table 3, was significantly longer than the pre-project quiz. It included student-reported perceptions on the impact of the project as used in previous semesters, a few repeat questions from the pre-project quiz, and inquiries about their own selected energy type and the results of their project. Note that highlighted questions 3, 4, 5, and 7 are almost identical to their corresponding questions in the pre-project quiz. In addition, a portion of Question 1, and Question 2 in its entirety, were developed to help assess ABET criteria related to lifelong learning (discussed in detail in [6]). Question 6 contained multiple parts and was designed to allow students to demonstrate retention of the concepts they learned and the experimental results they obtained through completion of their specific project.

**Table 3.** Post-project survey question topics for the Spring 2006 evaluation.

| | |
|---|---|
| **1** | Student perception of project's impact on understanding of energy needs and renewable energy *(rating from strongly agree – strongly disagree)* |
| **2** | Types of resources consulted or used to complete this project *(short answer list)* |
| **3** | Rank of energy sources based on their relative contribution to pollution levels *(rank five options)* |
| **4** | Top three renewable energy sources currently used for U.S. energy production *(circle three of six)* |

| | |
|---|---|
| **5** | Current cost of electricity, crude oil, gasoline, hydropower, solar power, and wind power *(fill in the blank)* |
| **6** | Detailed information about energy source studied, including history, advantage, disadvantage, measured efficiency, and prediction of future usage *(short answer)* |
| **7** | Biggest barrier to increasing worldwide usage of renewable energy sources *(short answer)* |

## IV. IMPACT OF RENEWABLE ENERGY PROJECTS

The new evaluation tool for the renewable energy projects was designed with three specific goals in mind. The first goal was to evaluate whether students felt the projects had an impact on their understanding of renewable energy, a subjective evaluation. The second purpose, addressed with the factual-based questions in both the pre-project and post-project surveys, was to attempt to determine objectively whether the projects increased student knowledge of energy topics. And finally, it was desired to evaluate whether students were retaining specific results of their projects and the completed experiments. The results indicate that some success was achieved in each of these three goals.

Student perceptions of the renewable energy projects clearly indicate the positive impact, as shown in Table 4. The Spring 2006 results mimic previous semesters (included from [6]), demonstrating that the majority of students perceived an increase in their understanding of energy topics and renewable energy sources as a result of these projects.

**Table 4.** Percentage of students responding positively (strongly agree or agree) to questions about energy concepts and renewable energy importance.

| | **Fall 2004** ***N=73*** | **Spring 2005** ***N=78*** | **Fall 2005** ***N=63*** | **Spring 2006** ***N=72*** |
|---|---|---|---|---|
| This project has increased my understanding of energy and global energy needs in general. (Spring 2006) | --- | --- | --- | 94.4 |
| This project has increased my understanding of alternative or renewable energy sources. | 100.0 | 97.4 | 95.2 | 100.0 |
| I believe that alternative or renewable energy is important for the future. | 98.6 | 100.0 | 98.4 | 98.6 |

Table 5 compares selected results from the questions found in both the pre-project quiz and the post-project assessment, from the Spring 2006 semester. It was found that although students recognized that oil and coal are top contributors to pollution levels (as compared to their renewable counterparts), the majority of students believe coal produces more pollution than oil.

**Table 5.** Comparison of energy awareness before and after renewable energy projects.

| | **BEFORE PROJECT** ***N=75*** | **AFTER PROJECT** ***N=72*** |
|---|---|---|
| Percentage of students reporting that oil and coal were top two relative contributors to pollution levels. *(of hydroelectric, coal, solar, oil, and wind)* | 96.0 | 100.0 |
| Percentage of students knowing that usage of oil is the number one contributor to pollution levels. | 44.0 | 33.0 |
| Percentage of students choosing the following as one of the top three renewable energy sources in use for U.S. energy production (actual top three are highlighted in yellow [7]): | | |
| Biomass | 14.7 | 23.6 |
| Geothermal | 34.7 | 47.2 |
| Hydrogen | 21.3 | 6.9 |
| Hydroelectric | 74.7 | 95.8 |
| Solar | 72.0 | 63.9 |
| Wind | 80.0 | 62.5 |
| Percentage of students knowing the correct approximate range of the cost per kWh on their own electric bill. | 17.3 | 41.7 |

Also from Table 5, it is encouraging to see that the project increased student awareness of the usage of renewable sources in the United States. As a result of these projects, most students learned of the significant contribution of hydroelectric energy in the U.S. renewable portfolio, as evidenced by the increase to 95.8 percent of the students choosing hydroelectric power as one of the top three sources. In addition, many students became more aware of biomass and geothermal as top sources, and recognized that hydrogen is not a primary contributor. However, over 60 percent of students still reported that solar and wind energy are in the top three U.S. renewable energy sources, which identifies room for improvement in the delivery of these projects.

Table 6 reports selected results from Question 6 of the expanded post-project survey, in which students were asked to provide outcomes from their own energy projects. Experimental energy conversion efficiencies of the student-built devices were generally low, but students did seem to learn through their research that real installations of these energy solutions are typically more efficient. It is interesting to note that the clean or non-polluting nature of the systems was the advantage listed most often for all three energy sources studied. The most-often listed disadvantage for each energy type showed more variety, which reflects the real sense that each energy type has its own unique application challenges.

**Table 6.** Student-reported project results and perceptions of three energy sources.

| | **HYDRO-POWER** | **SOLAR ENERGY** | **WIND ENERGY** |
|---|---|---|---|
| Percentage of students studying this energy source *(N=71)* | 39.4 % | 43.7 % | 16.9 % |
| Lowest reported experimental efficiency, %<br>Highest reported experimental efficiency, % | <1<br>24 | 1<br>15 | <1<br>8 |
| Efficiency of typical installation (range), % | 20-90 | 10-25 | 15-50 |
| Primary reported advantage | Clean, no/low pollution | Clean, no/low pollution | Clean, no/low pollution |
| Primary reported disadvantage | Disrupts ecosystem | Expensive | Location dependent |

## V. CONCLUSIONS

In response to a demonstrated need for curricula in renewable energy topics, semester-long group projects in renewable energy have been delivered in an introductory thermal science course since Fall 2004. The projects involve a detailed investigation of one renewable energy source, including a brief research study, the design, build, and testing of an experimental energy conversion apparatus, and an economic analysis. Previous assessment of the impact of the energy projects was positive and showed increased student understanding of renewable energy sources, but fell short of formally evaluating the contribution of the projects to the energy education needs of the future.

Recently, the evaluation tool for these projects was modified to allow more detailed assessment of the project results. The overall success and value of the renewable energy projects has been demonstrated further using the expanded evaluation tool. The results presented will be used to further develop the renewable energy projects and the next version of the evaluation tool. In addition, the student results identify possible areas for further emphasis in undergraduate engineering and technology curricula. These projects are easily implemented at other educational institutions, to help advance the overall state of education in renewable energy technologies.

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