

## **AC 2007-2568: INTRODUCING RENEWABLE ENERGY EDUCATION INTO ENGINEERING TECHNOLOGY PROGRAM**

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# **Introducing Renewable Energy Education into An Engineering Technology Program**

## **Abstract**

This paper presents the first stage to implement green energy education into an engineering technology program making use of a solar power generation station. As issues such as climate change, global warming, increased blackouts, and oil price fluctuation continue to pepper the news, it is likely that the use of renewable energy will become an increasing national priority that will affect the next generation of college students. It is apparent that there is still a widespread lack of understanding about the benefits of using alternative energy sources. As such, there is clearly a need to educate the community about sustainable energy and our institution provides an excellent venue for reaching a large audience in creative and effective ways. The solar system will serve as a demonstration platform for educating undergraduate students about contemporary renewable energy theory and technology. Key to this educational strategy is the development of projects that can assist in educating students in all aspects of renewable energy, thus, raising public awareness of the requirement to protect the environment.

## **Introduction**

A trademark of the United States' economic growth is an ever-increasing demand for energy, which has traditionally been met primarily by combusting the hydrocarbons found in fossil fuels. As national security and environmental concerns grow, renewable energy resources are gaining increased attention. Unfortunately, there is currently a lack of renewable energy coverage in engineering and technology curricula. Even with the progressive developments of non-traditional energy sources over the years, the U.S. still receives more than 90% of its energy from fossil and nuclear fuels. However, the use of renewable energy is increasing with applications including green power generation for homes, cottage industries, health clinics, and community centers. Illinois has abundant solar and wind resources and students will soon be asking for more curricular support in this area.

As issues such as climate change, global warming, increased blackouts, and oil price fluctuation continue to pepper the news<sup>1-3</sup>, it is likely that the use of renewable energy will become an increasing national priority that will affect the next generation of college students<sup>4</sup>. Indeed, a statewide survey<sup>5</sup> has found that the vast majority of American residents want to see more use and development of renewable energy sources such as wind and solar power. However, it is apparent<sup>6</sup> that there is still a widespread lack of understanding about the benefits of using alternative energy sources. As such, there is clearly a need to educate the public of sustainable energy and our institution provides the best venue for reaching a large audience in creative and effective ways.

An enormous benefit of "green" power is its impact on air quality and other aspects of the environment. According to the US government's Energy Information Administration, over one fourth of the air pollution produced by burning fossil fuels is a by-product of electric power production. Acid rain caused by emissions of sulfur dioxide during the burning of coal and oil,

has been reduced in the last 20 years, but has not been completely solved. Installing one kilowatt of solar electric will result in reducing emissions over the course of the 25-year minimum expected life of the panels, by the following amount<sup>7</sup>: Carbon dioxide (49,500 pounds); Nitrous oxides (125 pounds), and Sulfur dioxide (400 pounds). It's anticipated that 39,030 pounds of Carbon Dioxide will be saved every year. On average, around 2,615 trees would be required to offset this early emission<sup>8</sup>.

The disciplines of engineering and technology have a long history of adapting to the needs of industry and society so that they remain relevant over time. Thus, to help fill this current educational gap, teaching resources and a subsequent plan of action are necessary components to successful integration of renewable energy concepts into mainstream engineering and technology curricula. The purpose of this work is to incorporate renewable energy into engineering technology courses at Georgia Southern University (GSU) making use of a recently acquired solar power generation station. The solar system will serve as a demonstration platform for educating undergraduate students about contemporary renewable energy theory and technology. Key to this educational strategy is to develop projects that can assist in educating students in all aspects of renewable energy.

### **Traditional Energy Sources**

The U.S. Department of Energy has compiled much historical energy supply and consumption statistics over the years, and provides access to this data via the Energy Information Administration<sup>9</sup>. Based on this data, Figure 1 was developed, which depicts the history of U.S. energy consumption in terms of total energy used as well as the energy consumed from the primary fossil fuel and nuclear power sectors.

It is obvious that the United States has an insatiable appetite for energy. In 2003, it consumed a total of 98,155,587 billion BTU. Other than two slight declines (in the mid-1970s and the early 1980s), U.S. energy consumption has been steadily increasing over time. This is due, in part, to the advent of the micro computer, the information and technology revolution, the ubiquitous SUV, as well as increasing productivity in the industrial sector, not to mention population increases. Consequently, the consumption of all fossil fuels has also been increasing over time in order to meet this invariably growing demand.

Petroleum has historically been the single greatest energy source in the U.S., due in large part to transportation fuel needs, and thus its consumption closely parallels that of total energy consumption, at least up until the mid-1980s. In 2003, the U.S. consumed 39,674,104 billion BTU from petroleum. Subsequent to that point in time, the rate of increase for total energy consumption has been greater than that provided by petroleum alone, as evidenced by the slope of the consumption curves. Nuclear, coal, and natural gas are increasingly being used to help meet our increasing energy needs.

Consumption of natural gas, on the other hand, declined during the 1970s and early 1980s, from which point it has steadily increased every since. In 2003, natural gas provided 22,506,690 billion BTU. The utilization of coal to meet energy needs has steadily increased since the early 1960s. In 2003 it provided 22,707,069 billion BTU. The nuclear power sector has increasingly provided substantial energy to the nation since the early 1970s, and actually produced 7,972,521 billion BTU during 2003. As Figure 1 also illustrates, all traditional, non-renewable fossil and

nuclear fuels have consistently provided between 91 and 95% of the nation's energy supply, even as renewable alternative sources have progressed.

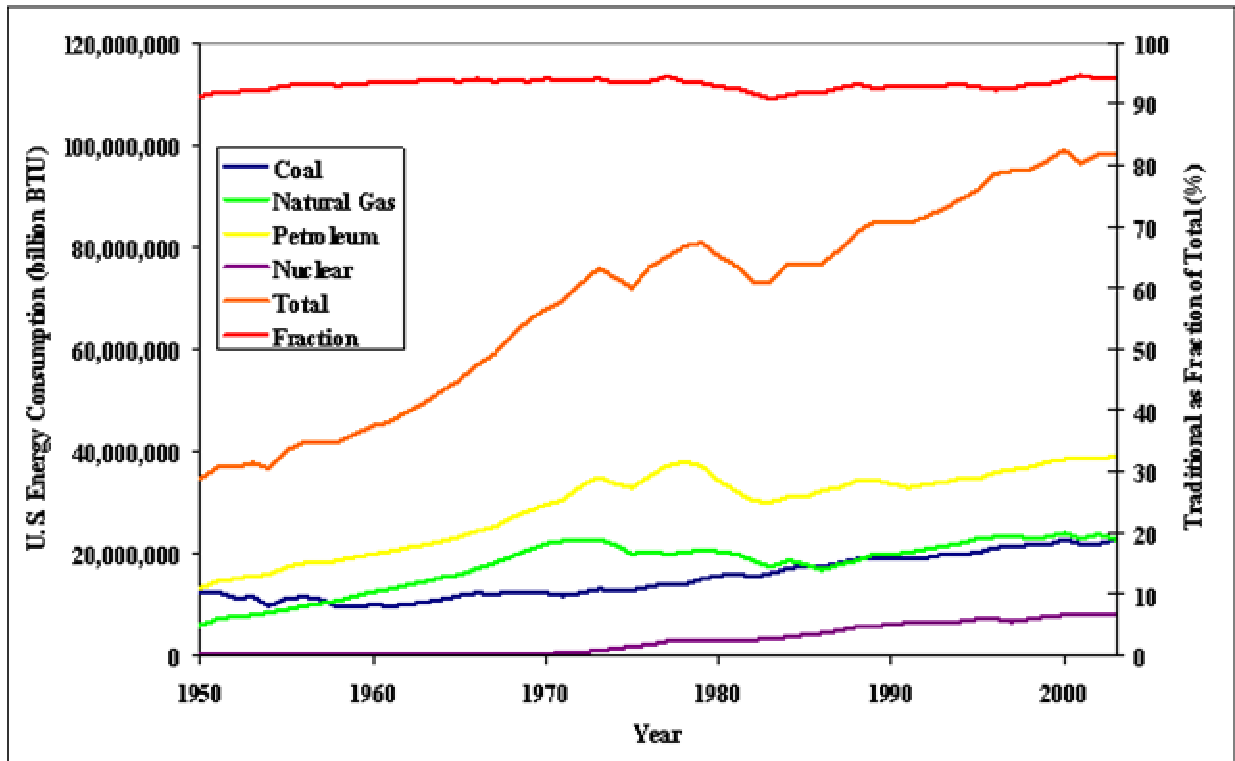


Figure 1: Historical non-renewable energy consumption in the U.S. (adapted from [1]).

## Renewable Energy Sources

Renewable energy alternatives include hydroelectric, wood, waste, geothermal, fuel alcohol, solar, and wind. The quantity of energy produced by all renewable sources, as shown in Figure 2, has been very slowly increasing over time. Historically, between 5.4 and 8.9% of the nation's energy has been supplied through these alternative technologies. This proportion was actually decreasing until the late 1970s, and due primarily to the energy crises, began to increase. It did so until the mid-1980s, after which it has been decreasing again, due to the increased use of fossil and nuclear fuels in order to meet the accelerated demand for energy that our growing economy needed. In 2003, renewable sources produced 6,149,537 billion BTU, which represented 6.27% of the nation's entire energy supply. This was only slightly lower than nuclear energy (22.8% less) alone. Thus renewable energy sources are beginning to play a substantial role in the nation's energy picture.

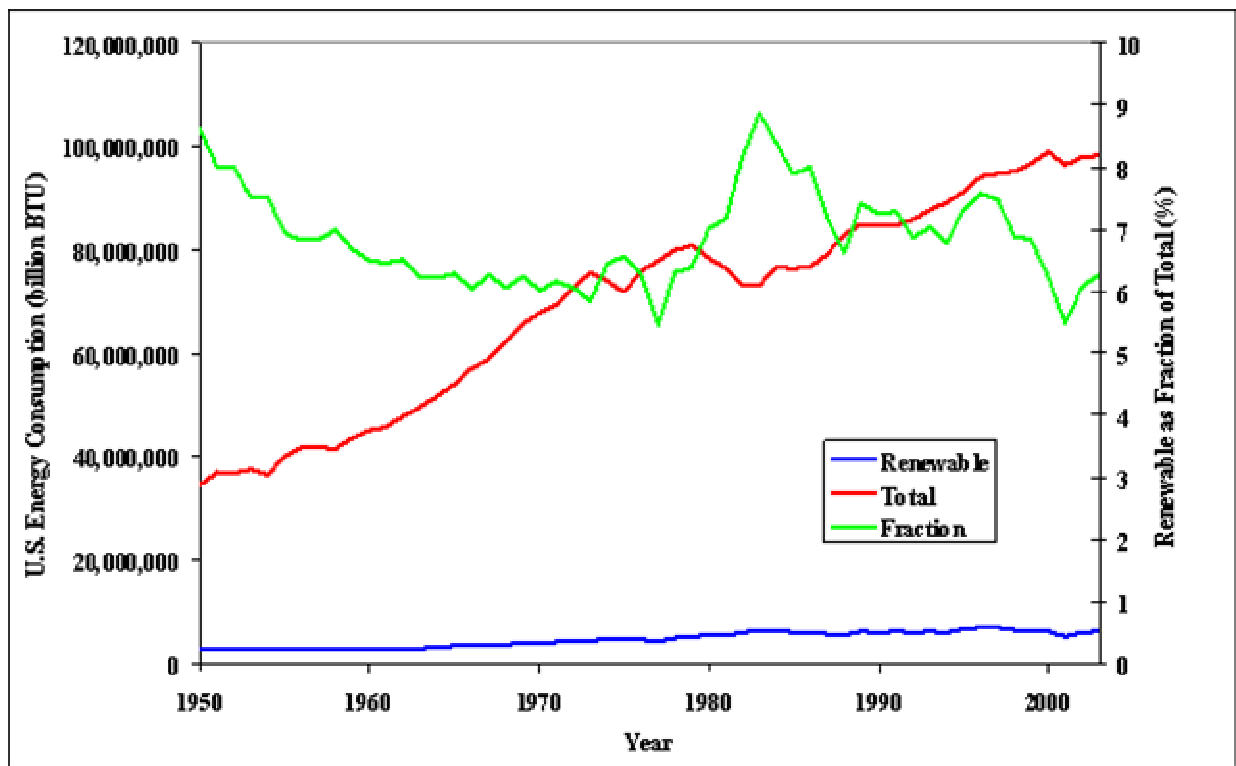


Figure 2: Historical renewable energy consumption in the U.S. (adapted from [1]).

## Renewable Energy Education

Energy is one of the most important inputs to industrial applications and production settings, and is thus a key for engineers and technologists to understand. Knowledge of the historic trends, current status, and future potentials of renewable energy resources in the U.S. is essential to engineering and technology graduates as we enter the 21<sup>st</sup> Century, as these technologies are poised to significantly alter the nation's energy portfolio.

Unfortunately, there is a serious lack of such curricula throughout the nation. Reference<sup>10</sup> discussed the current need and substantial opportunities to bolster renewable energy education in the U.S. The need to increase educational efforts regarding renewable energy is underscored by the lack of programs at the secondary, post-secondary, institutional, and national levels. As a case in point, during the last nine years, only seven papers (out of thousands) were presented at the national ASEE conferences (<http://www.asee.org>), that discussed teaching renewable energy concepts in the engineering and technology curricula. Moreover, during this time frame, seven papers were presented that focused on wind power, and 32 that discussed solar power. Much potential exists for increasing interest and improving teaching programs in this area.

America's schools spend more than \$6 billion each year on energy. The U.S. Department of Energy (DOE) estimates they could save 25 percent of that money with commonly available energy-efficient and renewable energy technologies<sup>11</sup>. Energy-Smart program was launched in 1998 to promote energy education. The initiative is focused on meeting these goals:

- Improve learning and teaching environments.
- Reduce energy consumption and costs.
- Increase use of clean energy.
- Increased energy awareness among students.
- Provide instructional material to teach students about the importance of energy conservation and efficiency through hands-on lessons.

To adequately cover the extensive range of possible topics that would be relevant to this paper, the authors recommend a full-semester stand-alone course. Table 1 presents core topics for such a course which, in conjunction with the other topics discussed in this paper, could readily be converted into a syllabus.

Table 1: Potential renewable energy course topics

Section	Topic
1	<b>INTRODUCTION</b> Definitions, historic energy consumption statistics, renewable options available
2	<b>FUNDAMENTAL CONCEPTS</b> Mathematics, physics, and chemistry concepts germane to production of renewable energy, unit conversions, etc.
3	<b>RENEWABLE RESOURCE BASE AND PRODUCTION</b> National production potential statistics, yields, properties, etc.
4	<b>HYDROELECTRIC ENERGY</b> Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
5	<b>WOOD ENERGY</b> Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
6	<b>WASTE ENERGY</b> Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
7	<b>FUEL ALCOHOL</b> Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
8	<b>GEOHERMAL ENERGY</b> Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
9	<b>SOLAR ENERGY</b> Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
10	<b>WIND ENERGY</b> Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
11	<b>ECONOMIC ANALYSIS OF RENEWABLE OPTIONS</b> Manufacturing processes, process economics, capital and operational expenditures, rate of return, payback, etc.
12	<b>ENVIRONMENTAL IMPACTS OF RENEWABLE ENERGY</b> Industrial and environmental regulations, industrial ecology concepts, etc.

For instructors who are interested in incorporating individual, specific learning modules into existing engineering and technology coursework at appropriate locations during the semester, as well as those who may design and implement entire courses devoted to renewable energy, supporting teaching materials are absolutely essential to success. Therefore, a brief listing of both recent textbooks as well as current websites is provided below in Appendix A. While not intended to be comprehensive, this list will provide an initial foundation for instructors who desire a basis for educational materials.

Understandably, not all academic programs will be able to accommodate this addition with all other programmatic requirements currently in place. Therefore, it is beneficial to examine other mechanisms for incorporating specific learning modules. Many approaches have been found to be quite successful vis-à-vis infusing particular educational topics into existing coursework.

Furthermore, integrating ethics instruction into undergraduate engineering and technology programs has been a popular topic in recent years<sup>12</sup>. The mechanisms that have been found useful to satisfy certain accreditation criteria such as ABET could thus serve as practical models for improved renewable energy education.

### **Program Scope and Assessments**

As discussed previously, this paper presents the first stage to implement green energy education into an engineering technology program making use of a solar power generation station recently required by the department. The solar system is currently under construction and will serve as a demonstration platform for educating undergraduate students about contemporary renewable energy theory and technology. Typical renewable energy topics would include developing curricula and integration into classroom activities. The following courses may be revised to incorporate renewable energy concepts and applications as follow:

- **Basic electricity and measurements:** A new chapter about renewable energy technologies can be added to include identification of various system components. Methods to collect system data and perform meter readings are appropriate to introduce at this level.
- **Electrical circuit analysis:** Equipped with data acquisition system, a solar system can provide real-time data streams via the Internet. Students should be able to examine and analyze on-line electricity production data to calculate hourly and daily amount of green energy produced. Furthermore, students could also be challenged to calculate the amount of greenhouse emission that would have been released had fossil fuel been used to generate this electricity.
- **Electric power generation and distribution:** This includes the operation characteristics of various renewable energy systems. For instance, specific power distributions and circuit protections as applied to solar system may be introduced and explained as an integral part of a power system course.
- **Industrial control and electronics:** Special topics dealing with power electronics, inverters, actuators, filtering, and data acquisition systems used in renewable energy systems may be

thoroughly covered in a typical power electronics course. Students should be able to quantify the quality of the generated electric signals using power spectrums and harmonics analyzers.

Moreover, student teams in appropriate courses may be formed to complete specific renewable energy projects. Current literature and best practices of renewable energy education can be used to engage students in creative ways. Samples of such activities<sup>13</sup> are given below for demonstration purposes:

*Project using data acquisition system:*

The data acquisition system collects data from several different sensors and sends them to the computer that posts the data on the internet where it can be monitored by students.

*Tasks*

1. With your team, observe the photovoltaic system. How many photovoltaic modules make up the system's array?
2. On your computer, go to the solar system website and locate the live data page. The section "System Specifications" tells about the solar system. The 'capacity' is how many watts of electricity your system is designed to produce. What is the total capacity (in watts) of the photovoltaic system?
3. Calculate the electric output of each module to see if they add up to the total capacity of the solar system.

*Project using comparable systems at other locations:*

Having heard about your solar system, your team is assigned to help other customers who are interested in how comparable systems would perform at their location. Following are questions that you may be asked:

- How much south-facing roof surface area is required for a similar installation using a 2 kWp-rated PV array?
- How much AC energy would a similar system with a 2 kWp-rated array produce in a different location?
- How does the output of the PV system compare to typical residential electrical load profiles?
- What is the DC to AC power conversion efficiency of this inverter as a function of power level and on a daily basis?
- How well does the inverter track the PV array maximum power point?
- How close to the rated output does the PV array operate in this application?
- How much of the load electrical load is satisfied by the PV system, both on a time of day basis and for the entire day?
- What is the maximum load that this system can operate under different solar insolation?

- How much energy (amp-hours and watt-hours) will a given module produce operating at peak power?
- What is the module operating current and power under actual operating conditions and as a function of solar irradiance?

A pre-designed written document to establish the problem statement and grading criterion for the student projects should be furnished early on. A rubric for scoring student performance tasks is depicted in Table 2. Each team is required to complete a detailed written report at the end of the semester including an oral presentation. Student teams should be able to progress to the point of completing their projects by a given date. They will also be expected to conduct research and acquire knowledge at their own pace. The instructor should prepare a summary report of this authentic learning experience which includes student evaluations. The students should be expected to rate the proposed experience in positive terms and feel proud of their accomplishment.

Table 2: Rubric for Task Assessments

<b>CATEGORY</b>	<b>4</b>	<b>3</b>	<b>2</b>	<b>1</b>
<b>Appearance and Organization</b>	Project report is typed and uses headings and to visually organize the material.	Project report is neatly handwritten and uses headings to visually organize the material.	Project report is written or typed, but formatting does not help organize the material.	Project report is handwritten and looks sloppy with cross-outs and multiple erasures.
<b>Abstract</b>	Approximately one paragraph. Tells detailed information about the report. Contains objectives of the work.	Does not completely explain the report in a concise manner. Purpose of the work is stated.	Does not explain the report in a concise manner. Purpose and objective of the work is unclear.	No abstract or the purpose and objective is not mentioned or unclear.
<b>Technical Discussion &amp; Interpretation Of Data</b>	All important trends and data comparisons have been interpreted correctly and discussed; good understanding of results is conveyed.	Some of the results have been correctly interpreted and discussed; partial understanding of results is still evident.	Incomplete or incorrect interpretation of trends and comparison of data indicating a lack of understanding of results.	Very incomplete interpretation of trends; lacks of directions/basic understanding of results.
<b>Figures, Tables, and/or Graphs</b>	Tables and Figures are logically formatted and polished in appearance. Information is readily conveyed. Titles are detailed and capable of standing alone.	Tables and Figures are included. A reasonable attempt is made at format. Some occasional mistakes are made.	Tables and Figures are include but Tables are split across pages without properly repeating title and column headings.	Tables and Figures are included but poorly thought out. Tables and Figures have no titles.
<b>Conclusions</b>	Student has a clear summary of what he/she learned and what the report was all about.	Summary is complete but does not clearly explain what student has accomplished.	Summary is too long or does not explain what the student accomplished.	Student has a summary that does not match the work in the activity.

## Conclusions

Renewable energy has traditionally been more expensive to produce compared to power generated from relatively inexpensive fossil fuels. Due to advances in technologies, as well as economies of scale, this is no longer always the case. The research, design, development, and deployment of alternative energy sources are indeed progressing. Unfortunately, all sources of renewable energy currently constitute only slightly more than 6% of the nation's entire energy supply. As the U.S. continues to voraciously increase its demand for energy, though, these non-traditional approaches will be imperative, especially as the topic of energy imports becomes viewed as a national security issue. Because the abundance of renewable energy resources holds much promise for our society, the next generation of students will need much more curricular support in this area, especially those engaged in engineering and technology programs. This is especially true as the issues of climate change, global warming, increased electricity blackouts, and oil price fluctuations continue to inundate the news. To date, however, many high schools, community colleges, and universities do not have robust educational programs in these critical fields. Electric power generation and renewable sources of energy are frequently discussed in the public media and are thus very vividly in the minds of students from daily life experiences. Combined with the fact that the public's general concern and interest for the environment has been increasing, the time for developing state of the art educational and outreach materials promoting "green technologies" has arrived. Hopefully the discussions provided in this paper can help provide momentum.

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## Biography

## Appendix A

Several resources exist to aid teachers in curriculum design. Below is a list of agencies with established programs that could assist in developing renewable energy curriculum in conjunction with the installation of solar or wind power systems:

### Websites

The National Renewable Energy Laboratory (NREL) is a Department of Energy lab involved in wind, solar, and other renewable energy field. Their web site has excellent information regarding the various renewable energy sources and an educational resource page at <http://www.nrel.gov/education>.

The DOE's Energy Smart Schools program (<http://www.eere.energy.gov/energysmartschools>) lists guidelines for building energy smart schools and is also an excellent source of information and curriculum building resources.

Interstate Renewable Energy Council's Schools Going Solar program contains information on other schools installing solar systems (<http://irecusa.org/schools/index.html>.)

Solar NOW has a comprehensive educational program dedicated to education in the field of alternative and renewable energy, with an emphasis on PV. As part of its curriculum package for the schools, Solar Now facilitates workshops for teachers, compiles curriculum resources, provides hands-on tools for students, and offers summer internships for high school and college students (<http://www.solarnow.org>.)

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