RENEWABLE ENERGY ALTERNATIVES – A GROWING OPPORTUNITY FOR ENGINEERING & TECHNOLOGY EDUCATION

by

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Abstract: *A hallmark 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 dearth of renewable energy coverage in engineering and technology curricula. The objectives of this paper are to examine historical energy data for both traditional as well as alternative energy sources, and to motivate educators to address this gap. 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. Explicit examination of the alternative energy sector reveals that hydroelectric power and wood combustion constitute the majority of the nation's renewable energy base. While still much smaller in scale, waste combustion, alcohol (i.e., fuel ethanol), and wind appear to be rapidly increasing in capacity, and are well-positioned to add significantly to the nation's energy supply in coming years. The trends discussed here and their implications will be critical for educators, students, and citizens, because contrary to conventional wisdom, simultaneously meeting the energy needs of our society as well as that of the environment are not mutually-exclusive.*

I. INTRODUCTION

Rapid economic growth rates require a supporting energy infrastructure. Historically the United States has met this increased demand for energy by procuring and combusting more fossil fuels. Environmental concerns at local, regional, and especially at international levels are shifting attention from these traditional, nonsustainable supplies to cleaner alternatives, many of which are sustainable and renewable. Renewable energy installations are being built around the world as utilities realize the benefits of adding clean, low-cost, reliable energy generation capabilities to their resource portfolios. Moreover, bio-based fuels are expected to help offset increasing needs as China and India continue their rapid economic expansions and demand more petroleum for transportation fuels. The use of alternative energy is also increasing in rural areas, especially in developing nations, with applications including village power systems, water pumping stations, homes, cottage industries, health clinics, and community centers. These developments should behoove us to be cognizant of our present energy base. Therefore, the objectives of this paper are to examine the current status of renewable energy sources vis-à-vis traditional energy supplies, to discuss the need for more curricular support in this area, and to provide suggestions for such development. The trends discussed here and their implications will be critical for educators as we enter the 21st Century.

II. STATUS OF RENEWABLE ENERGY IN THE U.S.

To fully appreciate the current extent of renewable energy utilization, it is useful to first examine the traditional energy resources that have historically supplied our country.

Traditional Energy Supplies

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 [1]. 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.

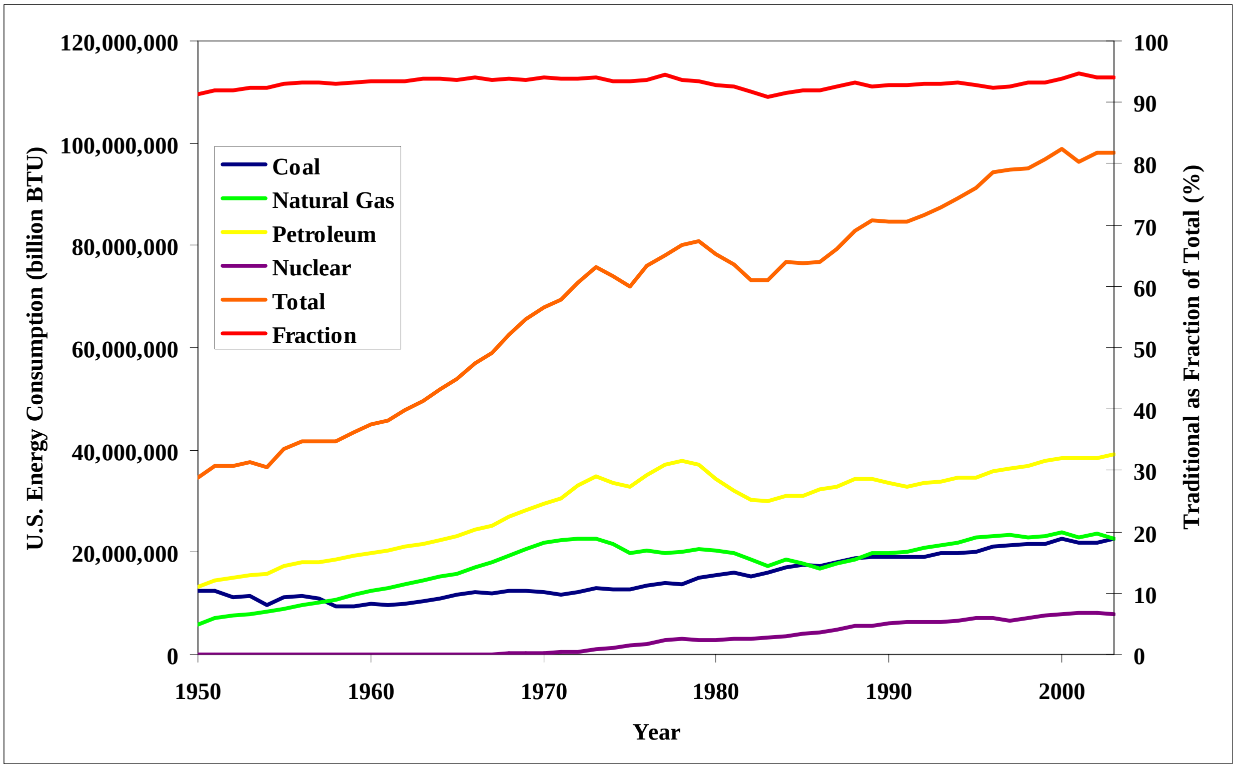

Figure 1. Historical non-renewable energy consumption in the U.S. (adapted from [1]).

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.

Renewable Energy Supplies

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.

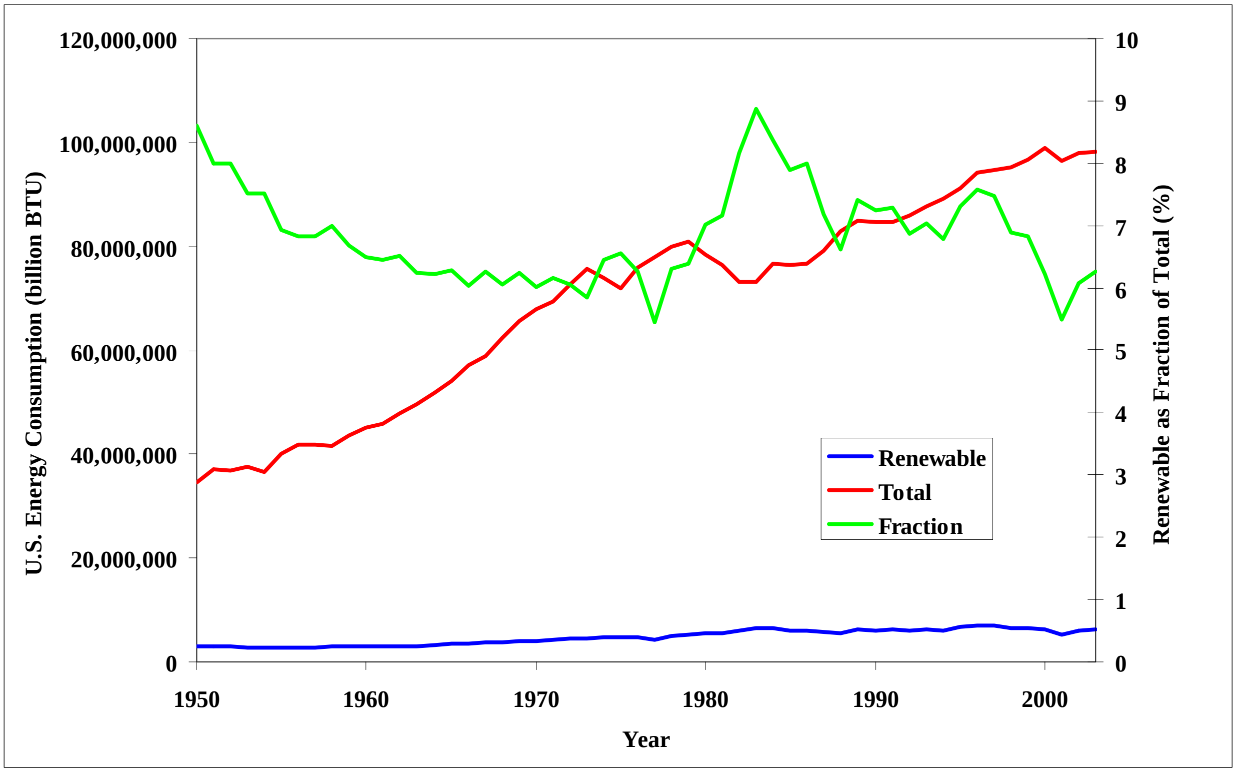

Figure 2. Historical renewable energy consumption in the U.S. (adapted from [1]).

Of all the sources of renewable energy, the two alternatives that have historically resulted in the greatest generation include hydroelectric and wood (Figure 3). The wood category includes the combustion of wood itself, wood waste, and black liquor (a processing waste). Hydroelectric power has historically been the single greatest source of renewable energy, and in 2003 produced 2,779,495 billion BTU of energy. During the last 54 years, this source of energy increased until the mid-1970s, after which point the reliability of this source of power began to fluctuate drastically. Currently, many questions abound regarding the dependability of this type of energy source, as well as the effects on surrounding ecosystems. Wood combustion, on the other hand, produced 2,086,393 billion BTU in 2003. This source of energy experienced a slight decline until the mid-1960s, and then underwent a slight increase in output until the mid-1970s. From that point until the early 1980s, it experienced a drastic increase, but has been declining ever since.

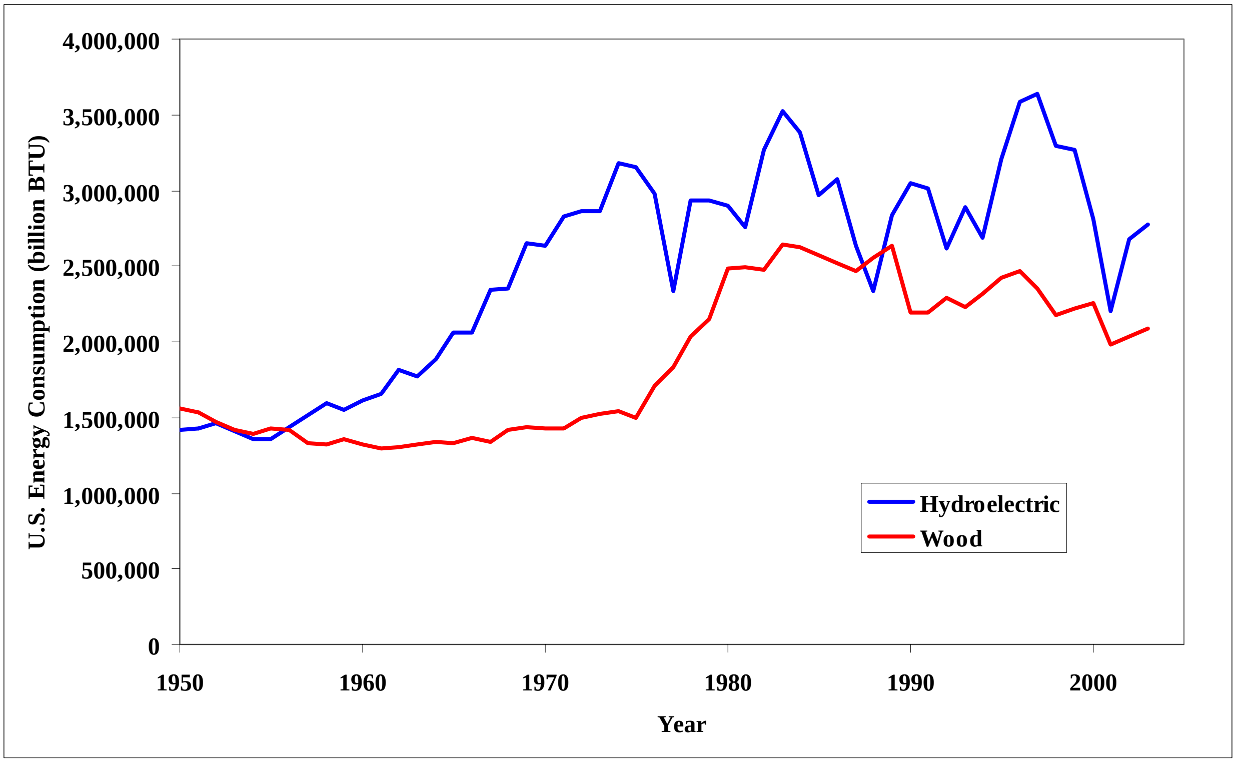

Figure 3. Historical consumption of most prevalent renewable energy supplies in the U.S. (adapted from [1]).

The remaining major alternative energy sources (Figure 4) include waste, alcohol, geothermal, solar, and wind. The production of energy from waste, which includes the combustion of municipal solid waste (MSW), landfill gas, sludge, tires, and biomass, began a drastic increase in the early 1980s. By the mid 1990s, however, production capacity began to fluctuate and decrease somewhat. In 2003, 558,426 billion BTU were produced from this energy source. Alcohol, in the form of fuel ethanol, is used as a blending agent and oxygenate in gasoline formulations for motor vehicles throughout much of the country, and produced 239,141 billion BTU in 2003. Since the early 1980s the utilization of this biofuel slowly increased until the mid-1990s, after which its use has drastically increased. In fact, of all renewable energies, the ethanol market is currently the energy alternative with the highest rate of growth. And it is expected to continue to have the greatest growth for the foreseeable future.

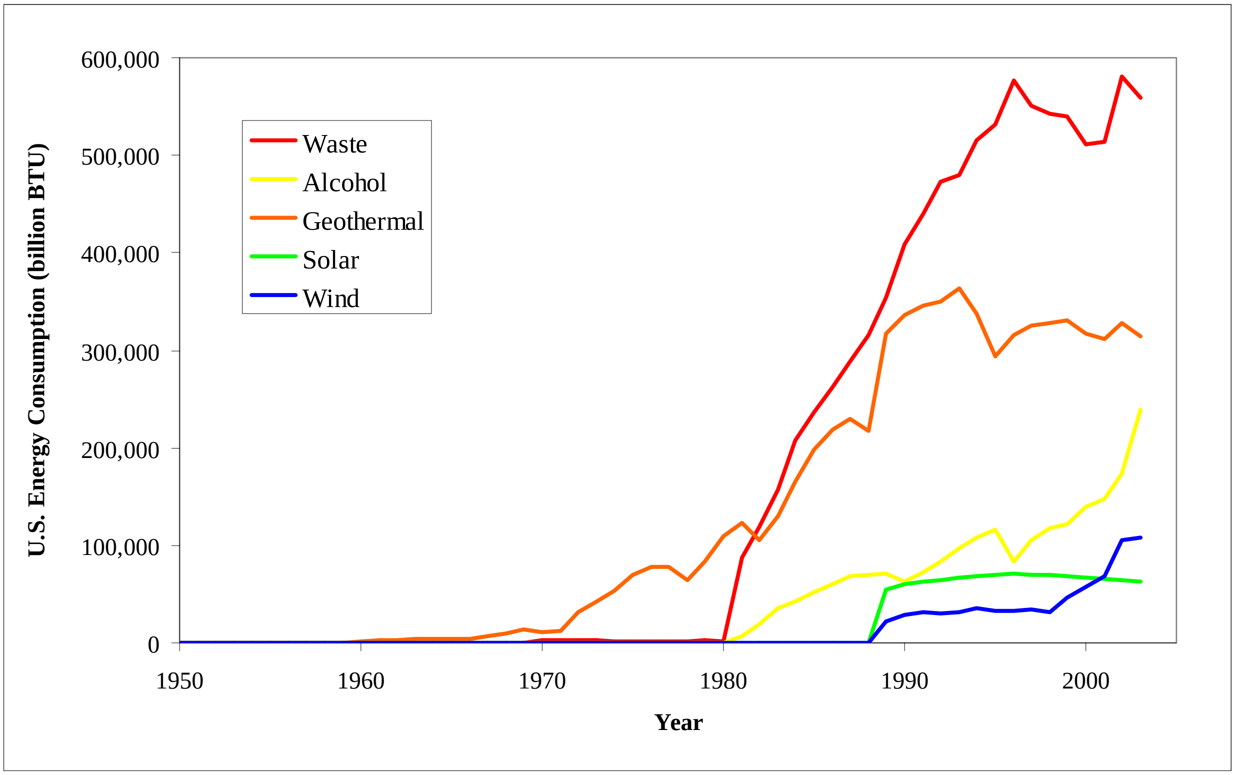

Figure 4. Historical consumption of other renewable energy supplies in the U.S. (adapted from [1]).

Geothermal energy produced 314,235 billion BTU in 2003. Its use began to increase from the mid-1960s until the early 1990s, after which it began to fluctuate and decline somewhat. Solar power, which includes use for thermal heating as well as photovoltaic electricity production, began to increase in the late 1980s, but has essentially stagnated since the early 1990s. In 2003, this energy sector only produced 63,412 billion BTU in the U.S. Wind power, though, produced 108,434 billion BTU in 2003, and since the late 1990s has been drastically increasing, and thus is poised to become a significant contributor to the renewable energy sector.

After having discussed the current levels of energy production from each of the renewable sectors, their historical trends, and the fraction of the nation's total energy supply that together they have historically produced, it is useful to examine the proportion of the total renewable energy supply that each has produced over time (Figure 5). As mentioned previously, hydroelectric and wood combustion have provided the majority of renewable energies over the last 54 years. But, since the early 1980s, the proportions due to the other alternatives have grown considerably, especially in the waste and geothermal sectors. In 2003, the 6,149,537 billion BTU that were produced by the entire renewable energy sector were produced as follows: 45.2% hydroelectric, 33.9% wood, 9.1% waste, 5.1% geothermal, 3.9% alcohol, 1.8% wind, and 1.0% solar.

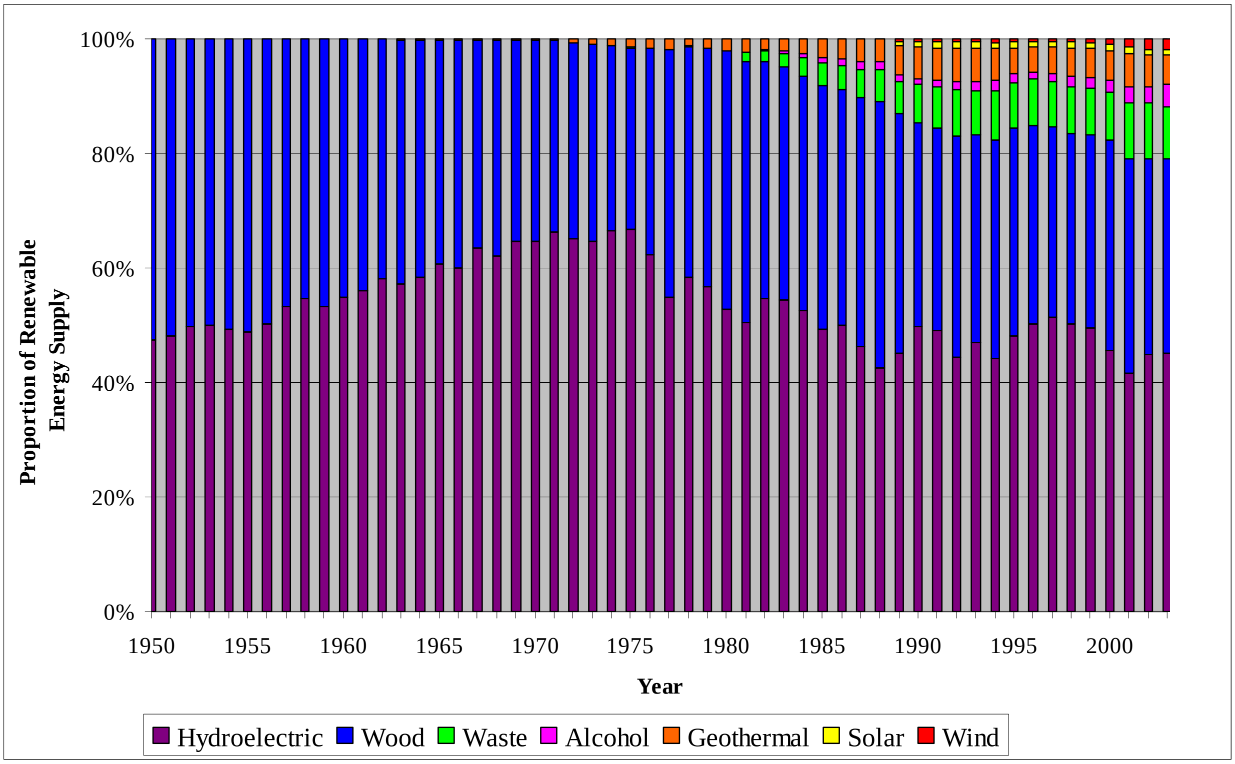

Figure 5. Historical proportions of all renewable energy consumption in the U.S. (adapted from [1]).

It is also instructive to consider the growth of each of these alternative energy sectors. Growth rates were determined from the original data by conducting linear regressions on energy consumption per year on a decade-by-decade basis, for each renewable energy sector. The original data set only included information through 2003, so growth rate determinations for the 2000s were actually calculated using a four-year basis only (2000-2003). Figure 6 depicts the calculated rates of growth for each renewable energy sector, for each of the previous four decades. Thus far in the 21st Century, only wood (quite substantially, in fact,) and solar (only slightly) production are experiencing a negative growth (i.e., a decrease in utilization) of -45,468 billion BTU/year and -986 billion BTU/year, respectively. Hydroelectric generation is currently experiencing a substantial growth of 37,859 billion BTU/year; waste is growing at 21,065 billion BTU/year; alcohol (i.e., fuel-grade ethanol) is growing at 32,633 billion BTU/year; geothermal is growing at 936 billion BTU/year; while wind is growing at 19,055 billion BTU/year. In terms of progressive alternative energy supplies, it appears that waste combustion, alcohol, and wind are well-poised to add significantly to the nation's energy needs in the foreseeable future.

A recent federal policy which has been widely publicized is the Energy Security Act of 2005 (PL 109-58). Known as the "Energy Bill", it articulates a comprehensive national energy strategy and encourages the development and use of renewable energy sources, including transportation fuels such as biodiesel and fuel alcohol. In fact, it establishes the Renewable Fuels Standard, which mandates the use of 7.5 billion gallons of ethanol in the nation's gasoline supply by 2012. This policy emphasizes the development, commercialization, and use of renewable energy sources, and considers them vital to meeting the growing demand for energy in the U.S.

As renewable sources continue to gain prevalence and acceptance, there will be a growing need for trained personnel in the workforce who are cognizant of the fundamental science underlying these energy supplies, and who can apply this knowledge to the design and deployment of industrial systems that incorporate these alternatives. Engineering and technology educators thus have an exciting opportunity to expand their traditional mission and to contribute to this coming wave of change in the nation.

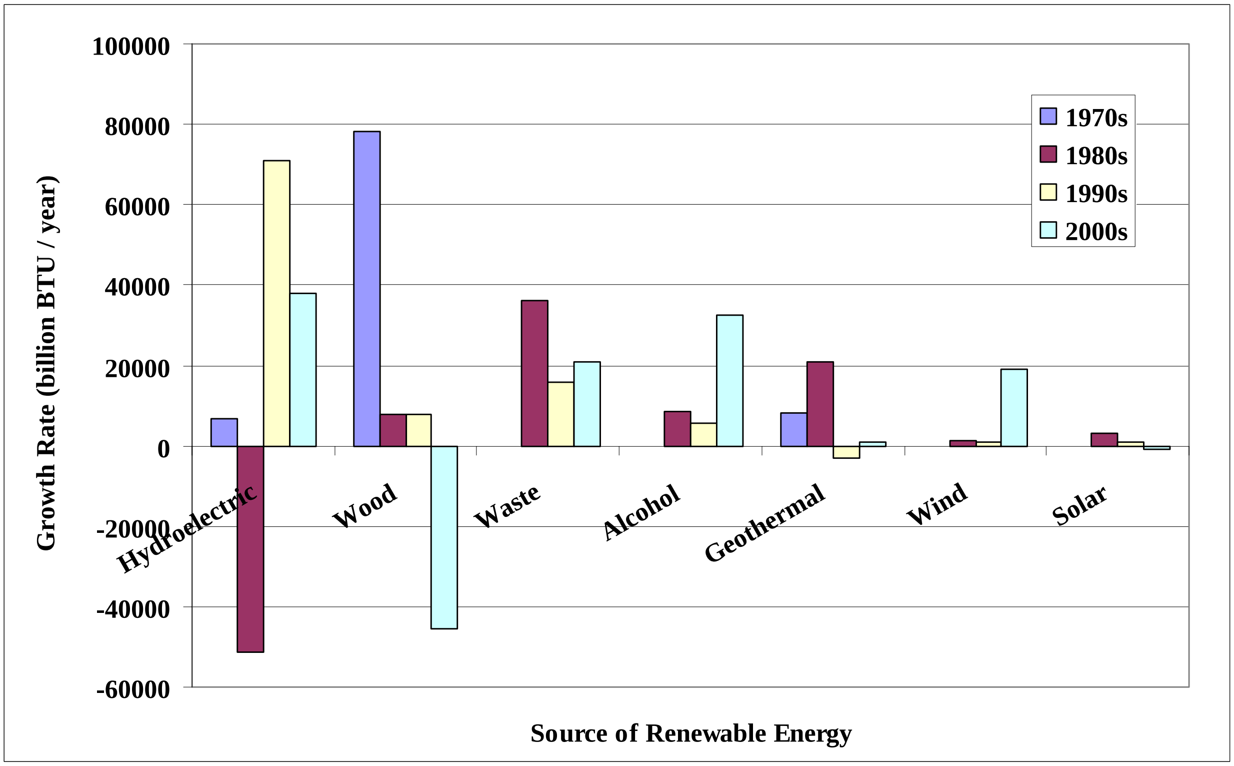

Figure 6. Calculated rates of growth for all renewable energy sources in the U.S.

III. RENEWABLE ENERGY EDUCATION

After examining and discussing current and historic energy generation, we must answer the following questions: Why is this information important? What is the relevance to engineering and technology education?

Energy is one of the most important inputs to industrial applications and production settings, and is thus 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 21st 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. [2] 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.

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.

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. While not intended to be comprehensive, this list will provide an initial foundation for instructors who desire a basis for educational materials.

Books

Berger, J. 1997. *Charging Ahead: The Business of Renewable Energy and What it Means for America*. Henry Holt & Co.
Berinstein, P. 2001. *Alternative Energy: Facts, Statistics, and Issues.* Oryx Press.
Boyle, G. 2004. *Renewable Energy*. Oxford University Press.
Boyle, G. 1996. *Renewable Energy: Power for a Sustainable Future.* Oxford University Press.
Boyle, G., Everett, B., Ramage, J. 2003. *Energy Systems and Sustainability*. Oxford University Press.
Ewing, R. 2003. *Power with Nature: Solar and Wind Energy Demystified.* Pixyjack Press.
Morgan, S. 2002. *Alternative Energy Sources*. Heinemann Library.
Scheer, H. 2004. *The Solar Economy.* Earthscan Publications.
Sorensen, B. 2004. *Renewable Energy*. Academic Press.
Walisiewicz, K., and Gribbin, J. 2002. *Alternative Energy*. International Thompson Publishing.

Websites

Clean Energy States Alliance
http://www.cleanenergystates.org/Funds/program.php?prog_id=15
National Renewable Energy Laboratory Educational Programs
http://www.nrel.gov/education/
Renewable Energy Policy Project
http://www.crest.org/index.html
Solar Energy International
http://www.solarenergy.org/

U.S. Department of Energy
 http://www.energy.gov
US Department of Energy Office of Energy Efficiency and Renewable Energy
 http://www.eere.energy.gov/

To adequately cover the extensive range of possible topics that would be relevant to this proposal, 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	**INTRODUCTION** Definitions, historic energy consumption statistics, renewable options available
2	**FUNDAMENTAL CONCEPTS** Mathematics, physics, and chemistry concepts germane to production of renewable energy, unit conversions, etc.
3	**RENEWABLE RESOURCE BASE AND PRODUCTION** National production potential statistics, yields, properties, etc.
4	**HYDROELECTRIC ENERGY** Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
5	**WOOD ENERGY** Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
6	**WASTE ENERGY** Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
7	**FUEL ALCOHOL** Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
8	**GEOTHERMAL ENERGY** Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
9	**SOLAR ENERGY** Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
10	**WIND ENERGY** Theoretical background, equipment and processes used, design and operational considerations, industrial and residential applications
11	**ECONOMIC ANALYSIS OF RENEWABLE OPTIONS** Manufacturing processes, process economics, capital and operational expenditures, rate of return, payback, etc.
12	**ENVIRONMENTAL IMPACTS OF RENEWABLE ENERGY** Industrial and environmental regulations, industrial ecology concepts, etc.

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 this instruction, either as individual topics, components, or units that can be used as specific learning modules, into existing coursework. Many approaches have been found to be quite successful vis-à-vis infusing specific educational topics into existing coursework. Integrating ethics instruction into undergraduate engineering and technology programs has been a popular topic in recent years [3]; the mechanisms that have been found useful in this arena could thus serve as practical models for improved renewable energy education. Some of these avenues include integrating focused components (theory as well as case study analyses) into specific technical courses [4; 5; 6; 7, 8], various components during technical problem solving in specific technical courses [9], issues and topics for review during capstone experiences [10; 11], topical seminars [12], as well as integration throughout the entire curriculum [13; 14; 15].

IV. 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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[2]. Goswami, D. Y. 2001. Present status of solar energy education. Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exhibition. Session 1433.

[3]. Dyrud, M. Ethics education for the third millennium. 1998. Proceedings of the 1998 American Society for Engineering Education Annual Conference & Exhibition. Session 1347.
[4]. Alenskis, B. A. 1997. Integrating ethics into an engineering technology course: an interspersed component approach. Proceedings of the 1997 American Society for Engineering Education Annual Conference & Exhibition. Session 2247.
[5]. Arnaldo, S. 1999. Teaching moral reasoning skills within standard civil engineering courses. Proceedings of the 1999 American Society for Engineering Education Annual Conference & Exhibition. Session 1615.
[6]. Case, E. 1998. Integrating professional ethics into technical courses in materials science. Proceedings of the 1998 American Society for Engineering Education Annual Conference & Exhibition, Session 1664.
[7]. Krishnamurthi, M. 1998. Integrating ethics into modelling courses in engineering. Proceedings of the 1998 American Society for Engineering Education Annual Conference & Exhibition. Session 2461.
[8]. Whiting, W., J. Shaeiwitz, R. Turton, and R. Cailie. 1998. 1998 ASEE Annual Conference Proceedings, Session 2213.
[9]. Rabins, M., C. Harris, J. Hanzlik. 1996. An NSF/Bovay endowment supported workshop to develop numerical problems associated with ethics cases for use in required undergraduate engineering courses. 1996 ASEE Annual Conference Proceedings, Session 3332.
[10]. Pappas, E. and J. Lesko. 2001. The communication-centered senior design class at Virginia Tech. Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exhibition, Session 1161.
[11]. Soudek, I. 1996. Teaching ethics to undergraduate engineering students: understanding professional responsibility through examples. 1996 ASEE Annual Conference Proceedings, Session 1661.
[12]. Alford, E. and T. Ward. 1999. Integrating ethics into the freshman curriculum: an interdisciplinary approach. Proceedings of the 1999 American Society for Engineering Education Annual Conference & Exhibition. Session 2561.
[13]. Davis, M. 1992. Integrating ethics into technical courses: IIT's experiment in its second year. 1992 ASEE Frontiers in Education Conference Proceedings, p. 64-68.
[14]. Leone, D. and B. Isaacs. 2001. Combining engineering design with professional ethics using an integrated learning block. Proceedings of the 2001 American Society for Engineering Education Annual Conference & Exhibition. Session 2525.
[15]. Marshall, J. and J. Marshall. 2003. Integrating ethics education into the engineering curriculum. Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exhibition. Session 1675.