RENEWABLE ENERGY ALTERNATIVES: CURRENT STATUS AND CAPACITIES

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ABSTRACT

A key to 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 environmental concerns grow, renewable energy resources are gaining increasing attention. To aid both researchers as well as educators, this paper examines historical energy data for both traditional as well as alternative energy sources. 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 has revealed 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 the coming years. The trends discussed here and their implications will be critical for both educators as well as researchers, because contrary to conventional wisdom, simultaneously meeting the energy needs of our society as well as that of the environment are not mutually-exclusive.

1. 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 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. 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 objective of this paper is to examine the current status of renewable energies vis-à-vis traditional energy supplies. The trends discussed here and their implications will be critical for both educators as well as researchers as we enter the 21st Century.

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

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

2.1. Traditional Energy Supplies

The U.S. Department of Energy has compiled much historical energy supply and consumption statistics, and provides access to this data via the Energy Information Administration (EIA, 2004). Based on this information, 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. Consequently, the consumption of all fossil fuels has also been increasing over time in order to meet this invariably increasing demand. Petroleum has historically been the single greatest energy source in the U.S., and thus its consumption closely parallels that of total

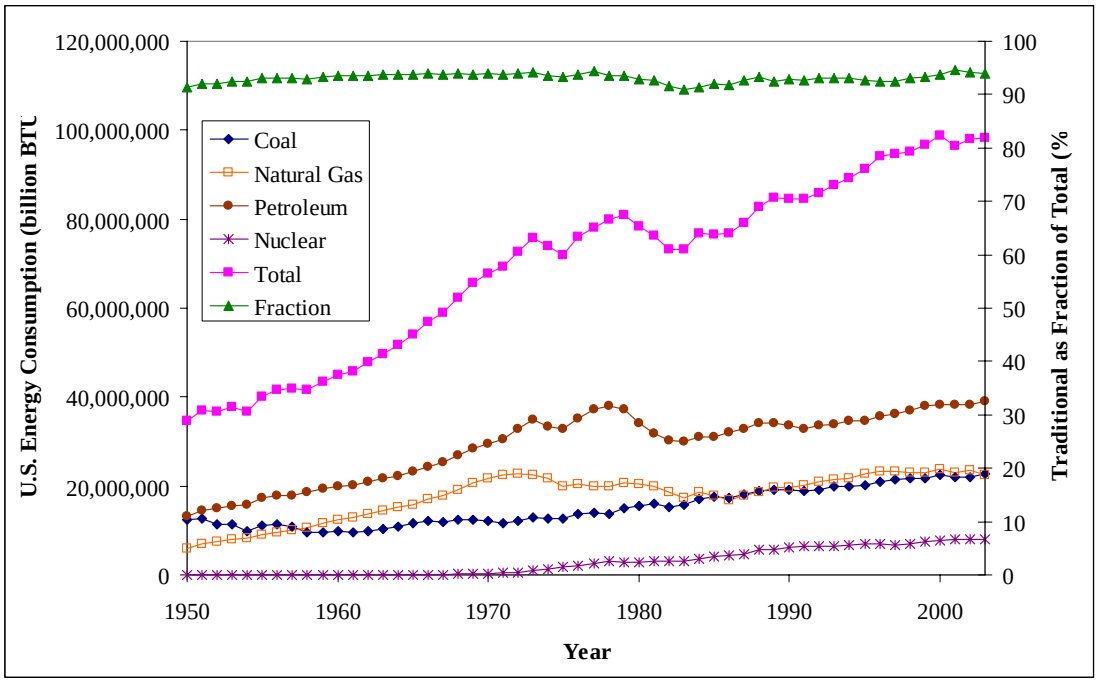

Figure 1: Historical non-renewable energy consumption in the U.S.

energy consumption, at least up until the mid-1980s. 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 the increasing consumption. In 2003, the U.S. consumed 39,674,104 billion BTU from petroleum.

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, 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.

2.2 Renewable Energy Supplies

The quantity of energy produced by renewable alternatives, 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 technologies. This proportion was, in fact, decreasing until the late 1970s, and due primarily to the energy crisis, 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 growing demand for energy. In 2003, renewable sources produced 6,149,537

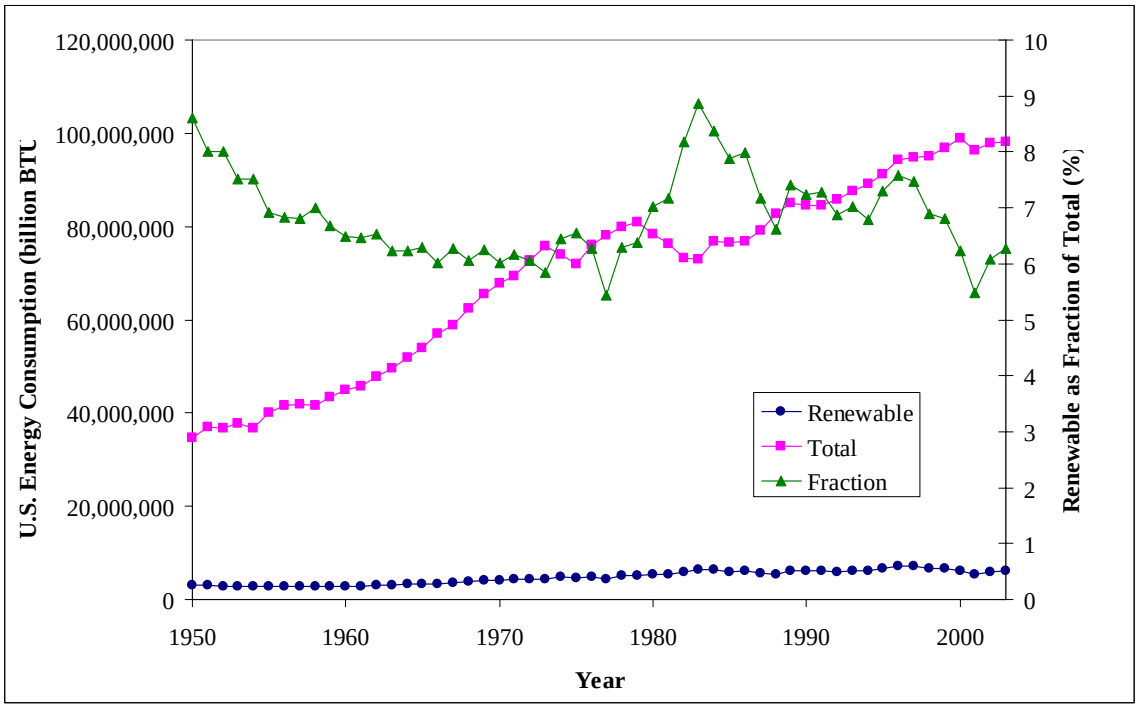

Figure 2: Historical renewable energy consumption in the U.S.

billion BTU, which represented 6.27% of the nation's entire energy supply. This was actually slightly lower (22.8%) than nuclear energy.

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.

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 its 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 ethanol, is used as a blending agent in gasoline formulations for motor vehicles, and produced 239,141 billion BTU in 2003. Since the early 1980s the utilization of this biofuel slowly improved until the mid-1990s, after which its use has drastically increased. In

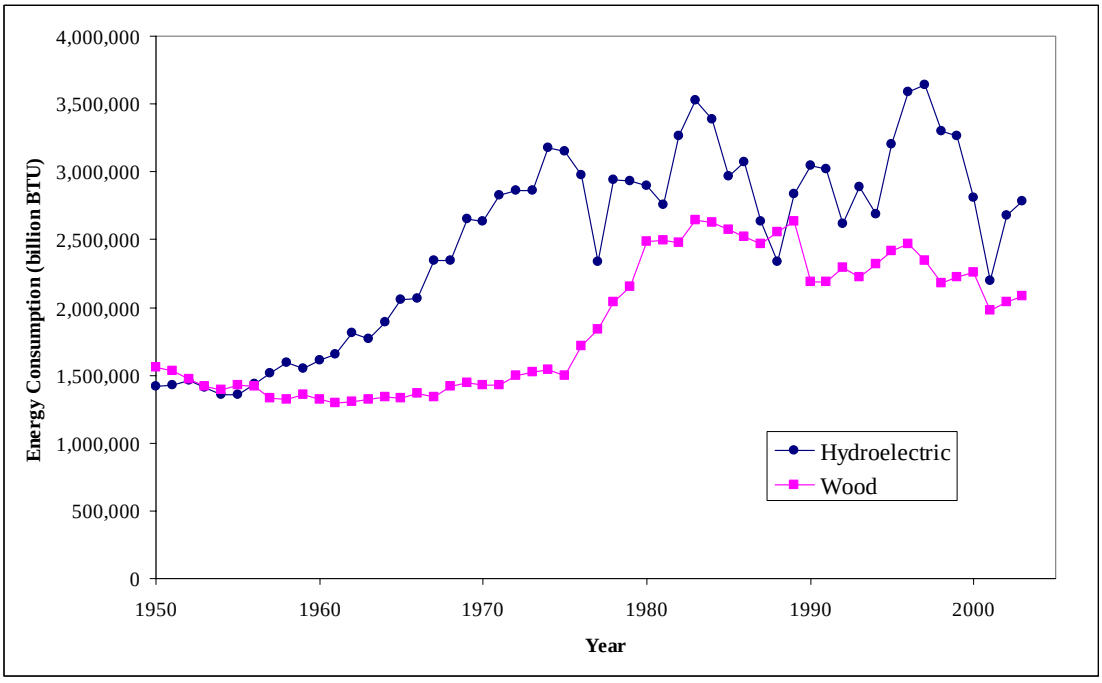

Figure 3: Historical consumption of most prevalent renewable energy supplies in the U.S.

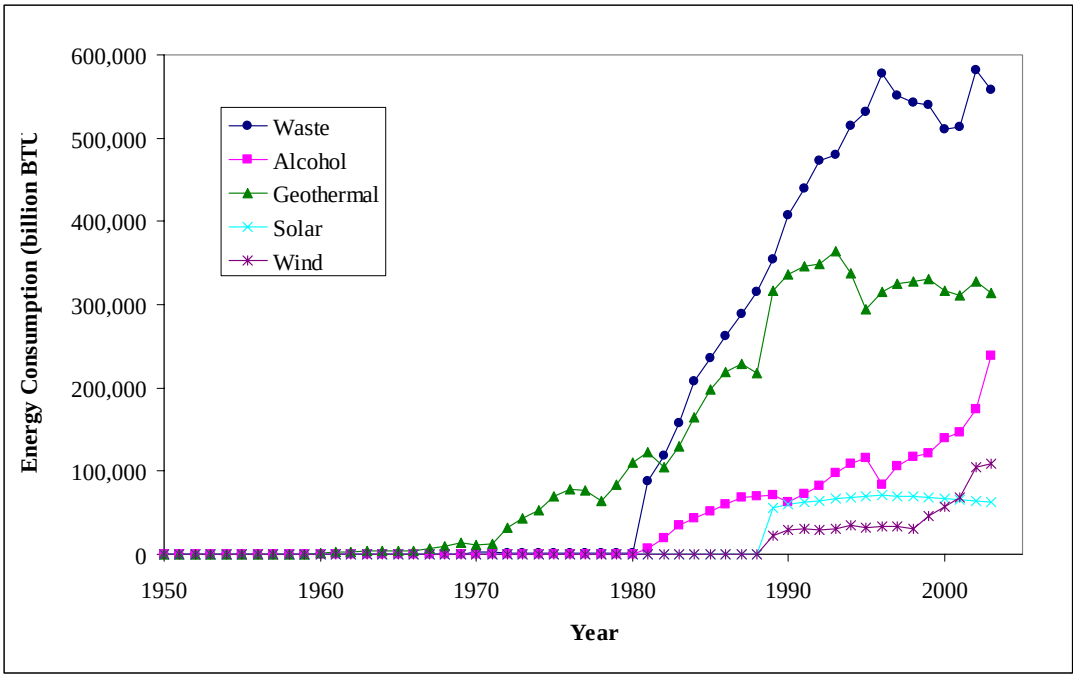

Figure 4: Historical consumption of other renewable energy supplies in the U.S.

fact, of all renewable energies, the ethanol market is currently the energy alternative with the highest rate of growth. Geothermal energy production produced 314,235 billion BTU in 2003.

Its use began to increase in 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 would be 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, 3.9% alcohol, 5.1% geothermal, 1.0% solar, and 1.8% wind.

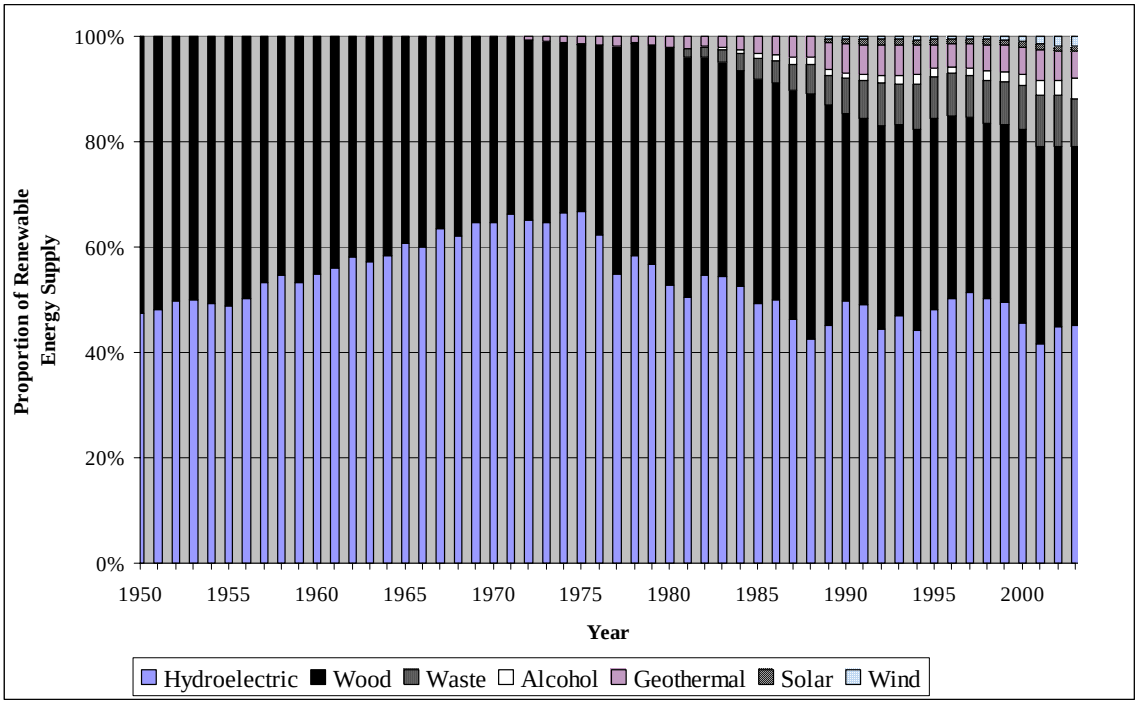

Figure 5: Historical proportions of all renewable energy consumption in the U.S.

It is also instructive to consider the growth of each of these alternative energy sectors. Growth rates were determined from the original data by calculating the average energy consumption per year, on a decade-by-decade basis. The original data set only included data up through 2003, so growth rate determination for the 2000s was actually calculated using a four-year basis, however. Figure 6 depicts rates of growth for each sector, for each of the previous four decades. Thus far in the current decade, only wood (quite substantially, in fact,) and solar (only slightly) production are experiencing a negative growth of -45,468 billion BTU/year and -986 billion BTU/year, respectively. Hydroelectric 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 coming years.

3. RENEWABLE ENERGY EDUCATION

An understanding of the historic trends and current status of renewable energy resources in the U.S. is essential to engineering and technology graduates as we enter the 21st Century, as are improved teaching programs in this area. Goswami (2001) discussed the current need and substantial opportunities to bolster renewable energy education in this country. 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

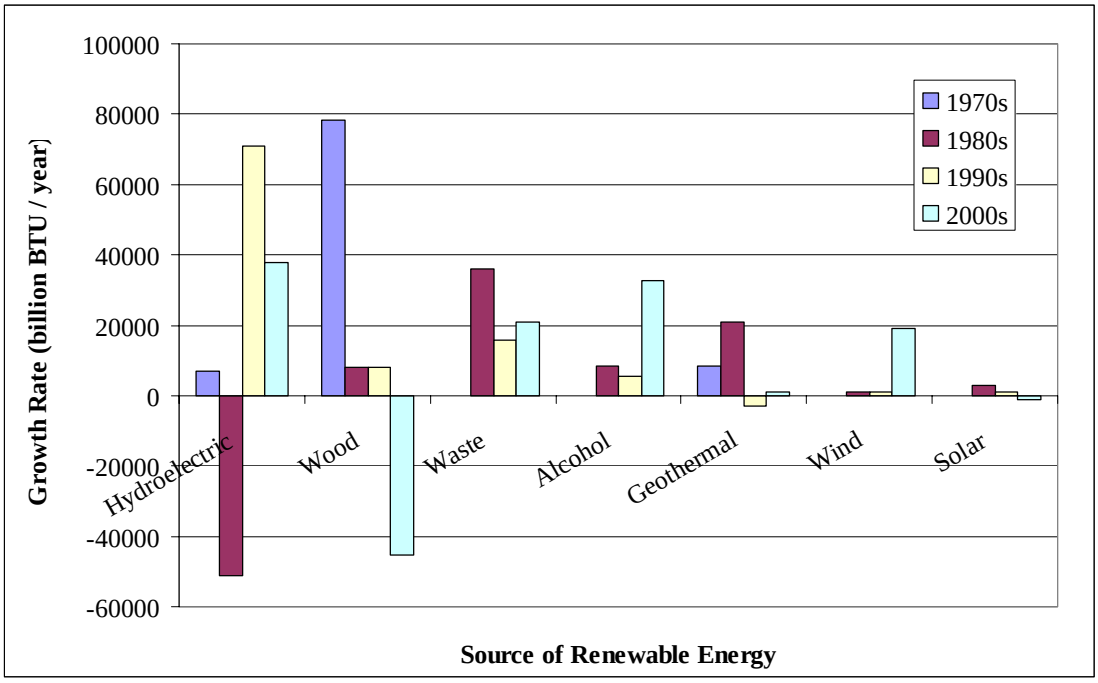

Figure 6: Calculated rates of growth for all renewable energy consumption in the U.S.

last nine years, only seven papers 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 specifically discussed solar power.

The disciplines of engineering and technology have had a long history of adapting to the needs of industry and society so that they will 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 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.

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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/
The US Department of Energy Office of Energy Efficiency and Renewable Energy
http://www.eere.energy.gov/
U.S. Department of Energy
http://www.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. 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 ethics education into existing coursework (Dyrud, 1998), and thus could 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 (Alenskis, 1997; Arnaldo, 1999; Case, 1998; Krishnamurthi, 1998; Whiting et al., 1998), various components during technical problem solving in specific technical courses (Rabins et al., 1996), issues and topics for review during capstone experiences (Pappas and Lesko, 2001; Soudek, 1996), topical seminars (Alford and Ward, 1999), as well as integration throughout the entire curriculum (Davis, 1992; Leone and Isaacs, 2001; Marshall and Marshall, 2003).

4. CONCLUSIONS

Renewable energy has traditionally been more expensive to produce compared to power generated from comparatively 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.

Because the abundance of renewable energy resources holds much promise for our society, the next generation of students will be asking for more curricular support in this area, especially those engaged in engineering and technology programs, especially 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.

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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.

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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.

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.

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.

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