Raising Community Energy Awareness: Building an Energy Display at the Mayborn Museum

Kenneth W. Van Treuren
Department of Mechanical Engineering
Baylor University

Ian A. Gravagne
Department of Electrical and Computer Engineering
Baylor University

Abstract

Energy is becoming an increasingly important topic in our lives. Watching the price of energy skyrocket, in particular electricity and gasoline, seems to elicit disapproval of the price increases but little more. America has become indifferent to energy issues and continues to pay the higher prices without much thought. This paper will begin by examining the state of the general public concerning energy and its lack of energy literacy. Most people have not begun to understand the complex nature of the energy challenge. Poor energy literacy led the authors to submit a proposal to a local foundation in 2006 to develop an "Energy Room" at the Mayborn Museum on the Baylor University campus. The Mayborn Museum is a facility that "provides a wide spectrum of learning opportunities to engage all types of visitors." Baylor University engineering students worked on several projects to support this project during their spring 2007 semester. The Senior Design Class installed a solar photo-voltaic panel and a Sevonious-type wind turbine on the roof of the museum. The controls for these alternative energy producers, as well as a static display solar panel and a second wind turbine, will be part of the public exhibit. For another part of the exhibit, seniors in the Mechanical Engineering Laboratory (ME Lab) course built a wind turbine display complete with LED lights to show the magnitude of the power produced when a fan was operated at various speeds. Another team of seniors in ME Lab instrumented wall simulations to measure the temperature drop across different insulation materials. A similar display on the effects of window treatments (single pane, double pane, and double pane with low E) was also developed. The desired result of these efforts is an energy display which will educate the general public on relevant energy issues. The display will also help the public understand ways that could both conserve energy and lower our dependence on hydrocarbon fuels. The students who participated on these projects were excited about contributing to a worthwhile activity. The projects also helped educate the students about energy as well.

The Case for Energy Education

People often assume that energy will always exist in forms and quantities that are inexpensive enough for a variety of personal uses. Today, it seems there is enough gas at the pumps so cars can have full tanks, electricity is almost always there to power lights and computers, and thermostats can be set to just about any comfortable temperature. Therefore, little thought is given to the abundance of these resources or the likelihood of these resources being available in the years to come. There is a great need for people to be informed about energy on all levels, from politicians who govern our energy industry to the average consumer[1].

Desperately needed are educational initiatives with a balance of technical and social content. This need for energy education is the main motivation for the energy awareness efforts at Baylor University. According to the National Energy Policy[2], the U. S. must have between 1,300 and 1,900 new electricity generation plants in place to meet the projected 45% increase in electrical demand by the year 2020. There is little chance that this need in new electricity generation plants will be satisfied. Economic and political policies often reflect the unspoken assumption that the United States will be able to continually increase its reliance on natural resources and more importantly, energy resources. Goals for “energy independence” have continually slipped since the term first appeared in 1980. For instance, with plentiful supplies, efficiency standards for cars have been often relaxed or postponed.

By avoiding the topic of energy demand and delaying discussion until a future time, the public does not perceive the impending problem of energy supplies. The problem actually may become worse[1]. The general public has the impression that technology is the answer and that technology will always provide the solution[3]. Again, this points to the need for energy education. The U.S., the number one consumer of energy in the world, is often looked to for leadership. If the United States does not identify, acknowledge, and then educate its people about the problems of energy, then it may be unrealistic to expect China’s emerging economy to have any consideration for energy usage and the impact of irresponsible energy usage on the global environment.

There are many issues surrounding a topic such as global warming that are not resolved. Global warming, though, is just one energy-related area where people find themselves ill-equipped to know what to believe. A survey conducted by the National Environmental Education and Training Foundation (NEETF) finds that people are often bewildered, or worse yet, may choose to ignore information because it is deemed “too complex” to understand[1]. Certainly, we should expect college graduates to be able to ask the right questions and then evaluate the answers they receive, but in the area of energy usage, Americans are clearly at a disadvantage. According to the NEETF survey, only 12 % of Americans correctly answered seven or more questions on a basic energy knowledge test[1]. Questions about trends in electrical energy generation, gas mileage for cars, and which sector of the economy uses the most energy were often answered incorrectly. Ironically, however, the survey finds that people often overestimate their energy knowledge. Clearly, this is an inconsistency that must be remedied through intensified educational efforts.

Successive generations will have to ask tough questions regarding energy[3,4] and must have the knowledge base with which to make wise decisions. The authors are advocating a concept termed *energy literacy* and are proposing to address a national need by developing energy literate students on campus. Energy literacy is also desired for people in the local community. But how is energy education best accomplished?

Several other organizations are also advocating energy literacy; including the Energy Literacy Project, the organization for National Energy Education Development, the Energy Information Administration, the National Energy Foundation and the NEETF. The general consensus of these organizations is that energy education is much needed. Unfortunately, while these organizations provide some resources, they do not seem to have a significant impact on the problem. An individual must be motivated to seek them out, implying that that person's interest has already been captured.

At the university level, the problem of energy literacy is being addressed in several areas. The first area addresses materials and teaching expertise for K-12 teachers[5,6,7]. Another idea is to include energy topics in courses that are already being conducted, such as thermodynamics, heat transfer and fluid mechanics[8, 9,10,11]. Other courses have been specifically developed as electives to address specialized topic areas[12,13]. Still other courses emphasize service learning[14,15,16]. Nevertheless, the state of energy education in higher education is dismal. For example, in 2001, one study found only 10 four-year colleges or universities regularly offering a solar energy course[17]. The energy education picture is likely somewhat better today, though we do not know how much better.

While all of these curricula address energy, most only deal with one aspect of energy, presenting either advanced technical engineering material (e.g. how electricity is generated) or purely social content (e.g. policy regarding energy usage). The same study[17] found a pressing need for energy courses that are accessible and available to non-technical majors, observing, "Bankers and other professionals are very important in achieving increased use of [alternative energy]; however, they are perhaps the least familiar with energy systems." Baylor is attempting to integrate both: to teach basic technical knowledge about energy and simultaneously to examine the social, political, and economic impact of energy-related decisions. Not only do engineers and scientists need to be smart concerning energy, but so do politicians, business professionals, journalists and homemakers. Everyone will eventually engage energy issues on several levels – in personal financial decisions, as part of a local workforce consuming energy to provide a good or service to society, and as one member of the global population bearing the impact of energy on world environments and economies. This desire to educate the students and general public led directly to the proposal to develop an "Energy Room" at Baylor University.

The Mayborn Museum Project

The Mayborn Museum Project began as an idea to build and install a laboratory exhibit focusing on alternative and renewable energy in Baylor University's Mayborn Museum. The museum is an exciting place where children of all ages can come and learn in a warm, friendly environment.[18] The Jeanes Discovery Center, a part of the museum, has 16 hands-on discovery rooms for interactive education. One of these rooms, the Energy Room, will house the permanent exhibit described in this paper. A proposal was made in 2006 to the Baylor/Waco Foundation which adopted and funded the project. The Baylor/Waco Foundation, founded in 1959, has

> "… served as the official hometown support group for Baylor University. Throughout the years, the foundation has utilized 100 percent of donations to sponsor projects at Baylor which enhance life in Waco and the surrounding area. In seeking to fulfill its mission, the Baylor/Waco Foundation partners with both individuals and businesses in the

> community, increasing awareness and securing funding for projects that serve both interests.[19]"

The concept behind the proposed project was to target three distinct demographics to help them learn more about energy in unique ways. For young children, there will be interactive hands-on elements that illustrate principals of alternative energy sources in action: photovoltaic (i.e. solar electricity), thermal (i.e. solar air and water heating), and wind. This exhibit will also appeal to junior and senior high students, an audience the museum wants to build, by revealing and explaining certain technical details of the exhibit. Lastly, the exhibit will serve as a laboratory for engineering students studying alternative and renewable energy at both the high school and college level. The exhibit will have a small photovoltaic system which was installed on the roof of Museum, powering a grid-tied DC-to-AC inverter that will feed electricity into the Museum's electrical system. Details of this installation will be visible to Museum patrons. Student branches of engineering service organizations including the American Society of Mechanical Engineers (ASME) and the Institute for Electrical and Electronics Engineers (IEEE) will assume responsibility for docent training and occasional demonstrations and lectures for visitors.

The National Energy Policy explains that the present geopolitical climate, combined with the dwindling discovery of new petroleum resources, will gradually force America to build and use renewable energy facilities in a widespread manner. Energy usage and costs touch all of us, and people can become quite excited about alternative and renewable energy when they can see and understand how it can be harnessed in their homes, farms and. unfortunately, in the central Texas region there are virtually no working residential renewable energy installations businesses, and only a handful of commercial installations. This sharply contrasts with neighboring cities to the north and south, in which a cadre of small businesses install thousands of solar pool, water, photovoltaic and wind systems each year.

Public education and awareness of other energy-related issues can immediately help people to make better decisions about personal energy usage and efficiency. The proposed exhibit will feature a "mock house," allowing us to interactively illustrate the energy impact of lighting, heating, air-conditioning, and appliances as well as the true costs and value of energy. The proposed project represents the first step in a larger vision for comprehensive energy education at the Museum, eventually including alternative fuels, fuel cells, large-scale power generation, and transportation. As a functional laboratory, new technologies can be adapted and tested with the results becoming part of the exhibit. The Museum provides an outstanding venue to stage the results.

Construction of the Wind and Solar Exhibits for the Mayborn Museum

The wind and solar exhibits for the museum were constructed as part of the senior capstone design class. "Senior Engineering Design II" is divided into sections of between 10 and 30 engineers of all disciplines. Each section is organized into a "company," with a project manager, departments and department heads, a budget and a project client. In this case, the Museum served as the client. The company was tasked to design and install, if possible, (1) a 1.1 kW (peak) photovoltaic (PV) array on the Museum roof, including a mounting structure to withstand 80mph straight-line winds, (2) a mounting structure for a small Sevonious-type wind turbine, (3) a grid-tie DC/AC inverter system with NEC-compliant disconnects and power meter, and (4) two embedded Ethernet controllers to report PV and turbine power statistics across the web and visually, in the exhibit area.

The class successfully met these requirements. Figures 1 through 3 illustrate several components. At present, various parts of the public exhibit are still under construction, so the rooftop PV and turbine have not been commissioned yet.

Figure 1. Students pose for a picture after installing six BP7185 185W (peak) PV modules and a powder-coated steel mounting structure on the Museum's standing-seam roof.

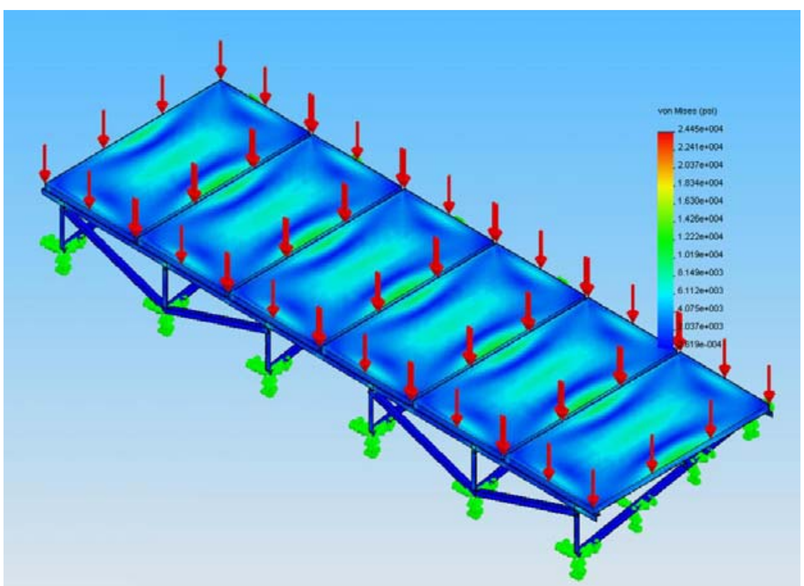

Figure 2. The PV rack system in SolidWorks, illustrating stresses from wind loading.

Figure 3. Two embedded Ethernet controllers with Power-Over-Ethernet (POE) capability, for reporting power statistics for the roof-top PV and turbine.

Construction of Energy Exhibits for the "Mock House"

The energy displays for the "mock house" were constructed as part of the senior Mechanical Engineering Laboratory course, working closely with the Museum staff. Two separate projects were undertaken by two teams consisting of three students each. The first team had the responsibility of developing a wind turbine demonstrator that would sit on the floor of the Energy Room[20]. This demonstrator has an operational wind turbine that would enable young children to visually observe that an increase in power correlates with an increase in wind speed. The concept was to develop a vertically mounted wind turbine in a Plexiglas case. The Plexiglas case was constructed on top of a base supplied by the museum staff. Housed in the base is a three speed squirrel cage blower that pulls air in from below the base. Because of the size of the case, air is directed from the blower to the wind turbine through a Plexiglas duct inside the case. On the front of the case are three buttons, a green, yellow and red button. Each button corresponds to one of the three speeds with green being the lowest and red being the highest speed. As the buttons are pushed, the operator is able to visually see the speed of the wind turbine increase. Corresponding to the increase in speed is an increase in power output of the wind turbine. A small microcontroller measures the power output of the turbine, and operates an LED array to visually indicate the output power. Incorporated into the activation of the blower is a timer circuit so the fan does not operate continuously. Airflow exits out the top of the unit into the room. A screen covers the top of the unit so that unwanted objects cannot be thrown into the interior of the unit.

Figure 4. Wind Turbine Demonstrator

The second group developed and tested the demonstrations that will be a part of the Energy Room[21]. Specifically, they designed a comparison experiment for different types of wall insulation. Small sample walls were constructed and filled with insulation materials. These wall units were instrumented with thermocouples to measure the temperature change across the insulations. Fiberglass, foam, cellulose and an un-insulated control wall were tested. For each wall that was tested, the best ten minutes of steady state data were taken and averaged to find the temperatures at each point in the wall. Using a value of 40 W/m^2 for the heat flux, the following results for temperature drop across the insulation, shown in Table 2, were obtained:

Table 1 Insulation Comparison

	∆T (°C)	R (ft^{2}hr°F/Btu)	Rated R-Value
Control (air)	36.15	5.14	1.01
Fiberglass	102.20	14.52	13.00
Polyurethane	75.39	10.71	13.00
Cellulose	64.68	9.19	13.00

The higher the temperature drop, the higher the R factor and the better the insulation is for not allowing energy to pass through the wall. This is the sort of information that the exhibit desires to make available to the general public. It will help people when they make construction choices for their homes. If nothing else, it will help them ask the right questions. Digital displays were purchased so that a temperature difference across each wall will be visible for visitors to compare. A heat lamp was used to irradiate one side of the wall. It was also desired to compare different types of windows. Small windows were also purchased and instrumented with thermocouples. One window is double pane, another is double pane with a Low-E coating, and third is a single pane window. Again, each window is irradiated and temperature differences across the window are measured, as shown in Table 2.

Table 2 Window Comparison

	∆T (°C)	U (Btu/ft^2hr°F)	Quoted U-Factor
Double Pane	10.01	0.70	0.60
Low-e	31.29	0.22	0.29

The U-factor is an overall heat transfer coefficient. The lower the number the more resistant the window is to passing through energy. Again, this is the kind of number that the general public needs to be aware of when they purchase windows or think about upgrading windows in a house. A visual display for the amount of energy transmitted through the windows is found by using a radiometer, a device that spins faster when more energy is incident on its paddles. Both the wall samples and windows will be incorporated into a sample wall that is being constructed in the Energy Room (see Figures 4 through 7). At this point in time, the sample wall is still under construction.

Table 3 Power Consumption

Appliance		Power Used (W)	Estimated Usage per day (hr)	kW-hr for one year	Cost for one year ($)
Incandescent Bulb		59	10	215.35	$38.76
Halogen Bulb		64	10	233.60	$42.05
Fluorescent Bulb		14	10	51.10	$9.20
Small TV	On:	35 - 50	6	109.50	$19.71
	Off:	0 - 3	18	19.71	$3.55
Large TV	On:	70 - 160	6	350.40	$63.07
	Off:	8	18	52.56	$9.46
DVD Player	On:	3 - 11	2	8.03	$1.45
	Off:	0 - 2	22	16.06	$2.89
Computer	On:	50 - 171	18	1123.47	$202.22
	Off:	5 - 10	6	21.90	$3.94
Phone Charger	On:	1 - 4	3	4.38	$0.79
	Off:	< 1			
Toaster	On:	760 - 1470	0.25	134.14	$24.14
	Off:	< 1			
Microwave	On:	925 - 1000	0.25	91.25	$16.43
	Off:	< 2			
Alarm Clock	On:	0 - 1	24	8.76	$1.58

A study was also done on the power consumed by the different light bulbs and appliances. The power consumed was determined by plugging in the appliance into a commercial device called a Kill-A-Watt power meter. Table 3 shows the energy consumption and a price estimate for a year of continuous usage for each appliance. This was calculated by assuming a certain amount of usage per day, and then calculating the energy used for an entire year. Each appliance was tested twice: once while turned on and in use, and once while they were turned off and not in use. This way, the maximum power consumption as well as the residual power consumption could both be measured for each device. The price was then calculated by assuming a price of $0.18/kW-hr. The main purpose of this chart is to give the average person an idea of how much their appliances are costing them to operate per year.

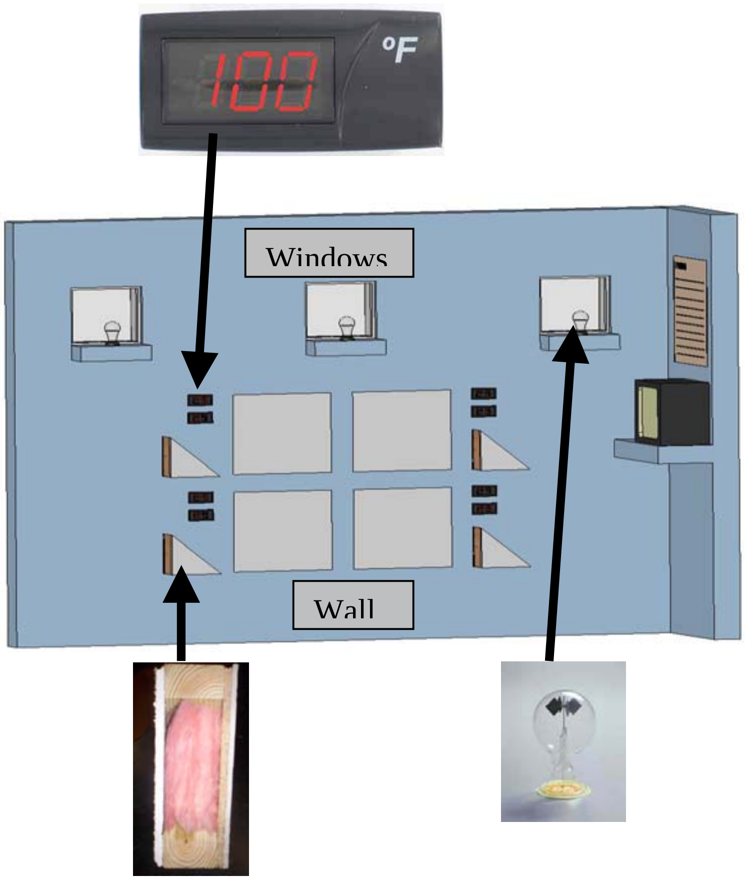

Figure 5. Wall with Displays for Energy Room

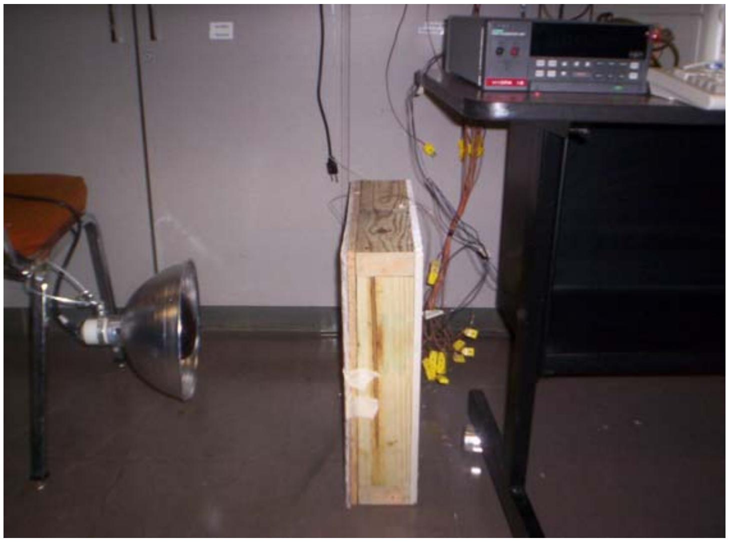

Figure 6. Experimental Wall Setup

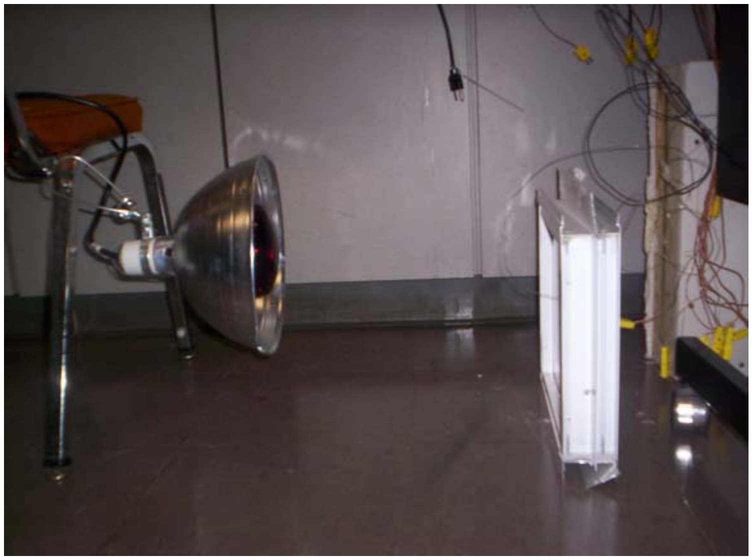

Figure 7. Experimental Window Setup

Conclusions

In the long run, energy and sustainability are bound only to increase in importance. Many researchers and authors feel that world energy usage is not only unsustainable, but that industrial economies will experience continuing volatility as non-renewable resources dwindle. Solutions must come not only from technical innovation, but also through changes in business practices, legislation, and personal choices. Individuals in all walks of life will be affected by the changing world energy situation. This project has the potential to elevate the general public and students' comprehension of the complete energy picture, and to give them tools that will remain relevant and useful throughout their lives and careers. In particular, to see renewable energy sources and energy conservation techniques in a residential setting will educate people and hopefully inspire them to want to learn more on these topics. Hopefully it will also inspire people to take measures to conserve energy through increased insulation for houses, improvements in windows, or possibly install a solar energy or wind power source in their residences.

References

1. RoperASW and NEETF, "Americans' Low 'Energy IQ:' A Risk to Our Energy Future," 10th Annual National Report Card: Energy Knowledge, Attitudes and Behavior, Aug 2002
2. U. S. Government Printing Office, Washington, D.C., "National Energy Policy: Reliable, Affordable, and Environmentally Sound Energy for America's Future," 2001
3. Goldblatt, David L., *Sustainable Energy Consumption and Society: Personal, Technological or Social Change?* Springer, 2005
4. Black, Edwin, *Internal Combustion: How Corporations and Governments Addicted the World to Oil and Derailed the Alternatives*, St. Martins Press, 2006
5. DeWaters, J., and Powers, S., "Improving Science Literacy Through Project-Based K-12 Outreach Efforts that Use Energy and Environmental Themes," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2006
6. Johnson, T. G., "A New Engineering Degree Program for Secondary School Teachers," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2004

7. Krohn, J. L., and Apple, S. C., "Energy and the Environment: An Energy Education Course for High School Teachers," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2003
8. Blekhman, D., and Mohammadzadeh, A., "Do Fuel Cell Topics Belong in a Combustion Course?" Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2006
9. Idowu, P., "Energy Systems and Conversion – Course and Content," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2003
10. Johnson, T. G., "A New Engineering Degree Program for Secondary School Teachers," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2004
11. Schumack, M., "Incorporation of an Energy Conversion Theme into Thermal Science Courses," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2002
12. Hodge, B. K., "Alternate Energy Systems – A New Elective?," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2002
13. Rosa, A. J., Predecki, P. K., and Edwards, G., "Technology 21 – A Course on Technology for Non-Technologists," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2004
14. Jansson. P. M., Stewart, J., Heston, W., Molner, R., Murphy, J., and Tomkiewicz, P., "Undergraduate Service Learning: Campus Photovoltaic System Siting, Design, and Permitting," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2005
15. Wies, R., and Aspnes, J. D., "Design of an Energy-Efficient Hybrid Power Source for Remote Locations as a Student Project," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2002
16. Weissbach, R. S., and Kephart, L. A., "Hybrid Renewable Energy System Analysis for Off-Grid Great Lakes Residental Housing," Proceedings of the American Society of Engineering Education Annual Conference and Exposition, 2005
17. Goswami, D.Y., "Present Status of Solar Energy Education," Proc. ASEE Annual Conf. and Exp., 2001, paper 2001-1433
18. http://www.baylor.edu/mayborn/index.php?id=15383 accessed on January 16, 2008.
19. http://www.baylor.edu/development/index.php?id=5330 accessed on February 5, 2008.
20. Cemo, T, Googe, M, and Fix, H., "Development of a Wind Turbine Demonstrator for the Mayborn Museum," ME Lab Project, Spring 2007
21. Eppink, J., Pruitt, J., and Wilkinson, M, "Development of Energy Displays for the Mayborn Museum Energy Room," ME Lab Project, Spring 2007

KENNETH W. VAN TREUREN
Dr. Van Treuren is a professor on the faculty in the Mechanical Engineering Department at Baylor University. He teaches the capstone Mechanical Engineering Laboratory course as well as courses in heat transfer, aerospace engineering, fluid mechanics, and wind power. His research interests include energy education and literacy and gas turbine heat transfer. He can be contacted at Kenneth_Van_Treuren@baylor.edu.

IAN A. GRAGAVNE
Dr. Gravagne is an assistant professor with the Electrical and Computer Engineering department at Baylor University. He teaches the Engineering Design II ("senior design") course, as well as technical electives in solar energy, robotics and engineering mathematics. His principal research interests are the engineering applications of dynamic equations on time scales and energy education. He can be contacted at Ian_Gravagne@baylor.edu.