AC 2008-2203: RENEWABLE ENERGY EDUCATION OF FUTURE ARMY LEADERS AT THE UNITED STATES MILITARY ACADEMY

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Abstract

The United States military is the world's single largest energy consumer, with an energy budget of over $10 billion each year. In this role, there is both a great responsibility and great opportunity for renewable and alternative energy stewardship on the national and global stage. Perhaps not well known to the public, is that the U.S. military is taking action to reduce energy consumption via widespread conservation programs, while at the same time supporting research and development of alternative energy technologies. However, the most effective measure to deviate from the conventional energy path is to educate the future decision makers, the future general officers of the Army, of the growing energy crisis and of the available and developing alternative energy options.

This paper discusses the evolving education of engineering students at the United States Military Academy to include a greater awareness of renewable and alternative energy. Similar to several civilian engineering programs, West Point offers a course on Energy Conversion Systems which covers conventional topics of fossil fuel utilization, combustion, advanced power and refrigeration cycles, direct energy conversion, chemical equilibrium, and so on. However, the course has evolved to reflect current energy issues, by including lessons on national and global energy usage, climate change, nuclear power, hydrogen, and renewable and alternative energy. In addition to this course, there are senior capstone projects and cadet independent studies that are connected to alternative energy research and development. The goals are to provide a broad overview to the cadets, such that the cadets are excited to continue the pursuit of energy alternatives as graduates and future leaders.

Energy Use in the United States

The United States consumes 100 Quad (1 Quad = 10^{15} Btu) of energy annually, accounting for roughly one quarter of the world's total consumption.[1] Figure 1 shows that 85% is derived from fossil fuels. There is ongoing debate over how long fossil fuel reserves will last, a few decades to a few centuries, depending on the fuel. But this debate is trivial, because they are all finite resources that will eventually be exhausted. The only debate is how quickly society must react to the inevitable end of unsustainable consumption.

The public is reluctant to plan for decades or centuries ahead, because personal financial and security concerns are more immediate. For successful development of energy alternatives, there needs to be a good motivator, as the energy crisis of the 1970s proved to be until oil prices again dropped. However this time around, the $100 per barrel oil price is not likely to fall because the rules of supply and demand now dominate over the rules of OPEC and other oil producing nations. The demand will not subside and is exceeding oil production, especially as China and India race to achieve the same quality of life that is enjoyed in the U.S. Quality of life is directly related to per capita energy consumption as shown in Figure 2. If the world's population is expected to plateau at 10 billion inhabitants by the year 2050, an annual energy consumption of

2,000 Quad will result, or five times the current amount. Energy prices will indeed continue to rise, and grassroots efforts to develop renewable energy are now finding strong support from the consumer.

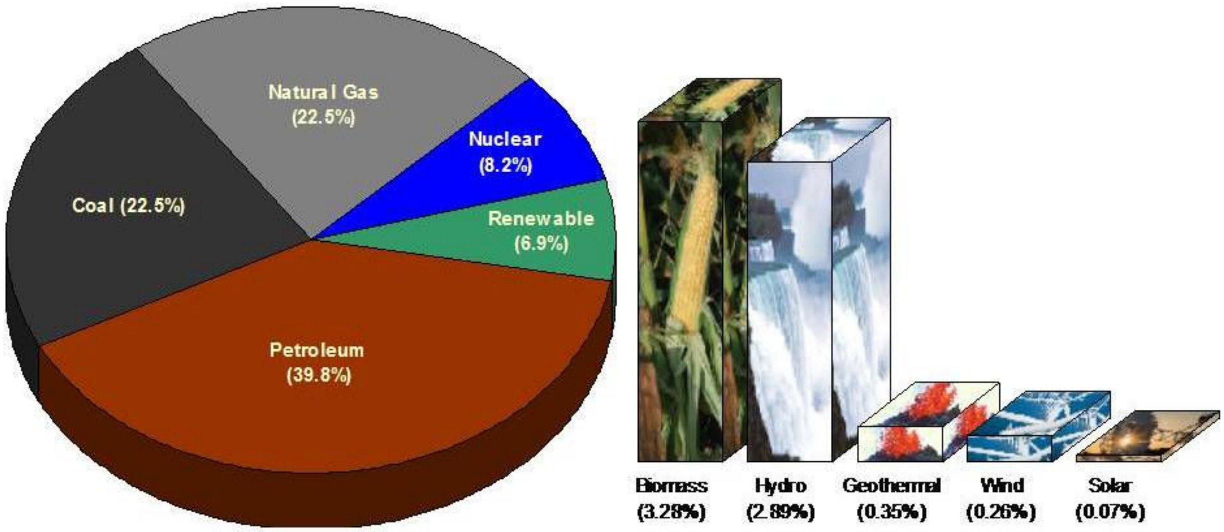

Figure 1 U.S. Energy consumption in 2006[1]

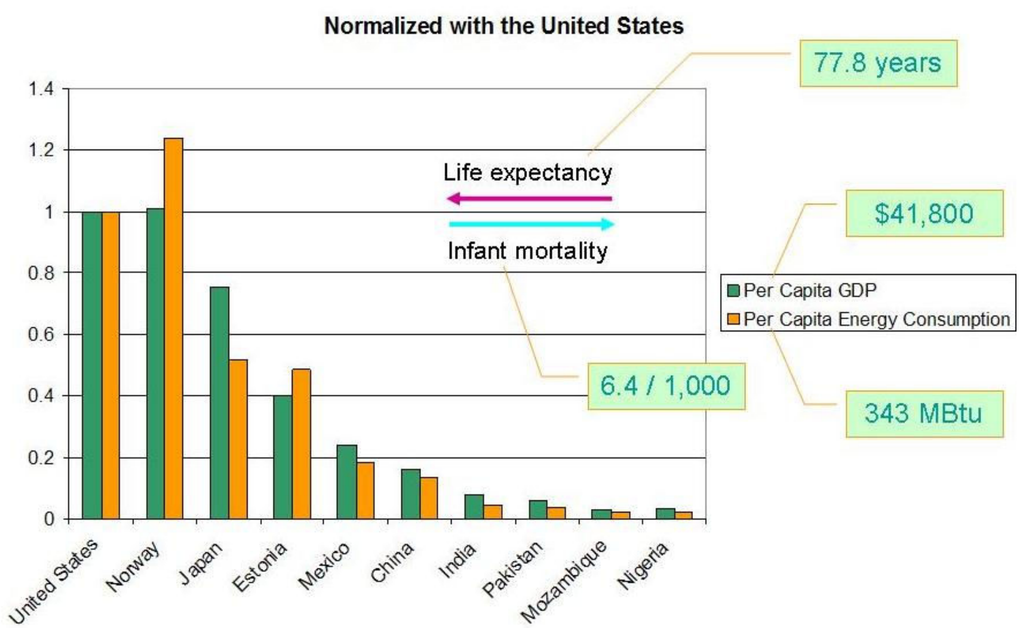

Figure 2 GDP and per capita energy consumption normalized with the U.S.

Academia is responding. It seems that there is a surge of interest in academia to scratch the alternative energy itch, similar to the development of environmental engineering programs 20 years earlier. Courses are evolving and being developed at U.S. universities which can be generally classified under renewable energy, alternative energy, or energy sustainability. Each has further classifications and an emphasis on the particular program it falls under, such as Chemistry, Physics, Chemical Engineering, or Mechanical Engineering. Some universities have gone so far as to offer a minor in related fields. A sizeable listing of relevant programs is available online.[2]

Energy Use in the Department of Defense

The U.S. Department of Defense (DoD) is the world's largest single user of energy, with an annual energy budget of over $10 billion. The U.S. government accounts for only 2% of the total U.S. petroleum consumption of 21 million barrels per day (bbl/day), but the DoD claims 93% of this amount.[3] The Air Force accounts for 57% of DoD petroleum use to supply its thirsty aircraft fleet, while the Navy takes 33% and the Army only 9%.[4]

Studies have shown that the average price of JP-8, the standard logistical fuel of the military, costs $40 per gallon in combat operations. This is an order of magnitude higher than the pump cost owing to the added personnel and equipment expenses to supply the fuel to the soldier. Many estimates put this cost even higher at $400-$600 per gallon, for fuel that must be delivered under the most extreme situations during combat operations. There is great financial incentive for finding fuel alternatives and improving efficiencies, and tactical advantages of reducing the number of vulnerable fuel convoys needed in theater. 70% of deployment weight is fuel, which if reduced will yield a faster and more effective force.[5]

While fuel is the lifeblood of vehicles and stationary platforms, the individual soldier relies on batteries to power communications, GPS, night-vision goggles, real-time instruments for situational awareness and many other devices that provide a technological advantage over the enemy. During a 3-4 day mission, the battery weight for a soldier can exceed 20 lb, and the demand for electrical power is only increasing as soldier technology becomes more sophisticated.[6] Several innovative systems are being explored to provide individual soldier power, and the DoD in 2007 initiated the Wearable Power Competition to reduce this weight burden more than 50% without any decrease in effectiveness. The necessity for alternative energy systems is evidenced by the offering of $1 million as the top prize.[7]

Energy Education at West Point

The United States Military Academy (USMA) at West Point is the oldest engineering institution in the nation, founded in 1802 as means to educate future officers in the art of military tactics and engineering. The mission of the USMA is:

> "To educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country and prepared for a career of professional excellence and service to the Nation as an officer in the United States Army." [8]

There are over 4,000 undergraduate students studying in 13 academic departments, each striving to meet the Academy's mission. In addition to the common requirement of 26 core courses, each student must take a minimum of 3 engineering courses, regardless of their major, echoing the historical foundation of the Academy and inherent value of problem solving skills for an officer. In addition to receiving an accredited undergraduate education, students receive rigorous military and physical training during their 47 month experience at West Point. Upon graduation, the cadets are commissioned as 2^{nd} Lieutenants in the Army and continue to serve for a period of at least 5 years active duty and 3 years reserve.

The current national and Department of Defense emphasis towards seeking alternative energy sources and technology is resonating through the U.S. Military Academy. In the Department of Civil and Mechanical Engineering at West Point, a senior level course on Energy Conversion Systems (ME472) has been taught for over 20 years.[9] The purpose of the course has always been to educate and inspire cadets regarding advanced energy systems, and the content evolves with the needs of the time. Traditional emphasis has been in the areas of advanced power cycles, cogeneration, combustion and reacting mixture thermodynamics, energy storage, advanced refrigeration cycles, and direct energy conversion devices. The overarching emphasis was on more efficient utilization of fossil fuels. While solar and renewable energy sources were covered in the early 1980s in response to the oil crisis, this was phased out as oil prices fell.

ME472 Energy Conversion Systems

Recent trends at the USMA reflect the needs of the military and nation as society gradually begins to phase out the age of oil. Through a variety of cadet senior projects, independent study research activities and the ME472 Energy Conversion Systems course, alternative energy resources and emerging technologies are presented to the next generation of officers and leaders. It is imperative to educate those in the military *and* civilian leadership that will be making the decisions. The current course objectives of ME472 are given below.

a. Analyze conventional thermal power systems using the 1^{st} and 2^{nd} Laws of Thermodynamics, exergy-based thermoeconomics, and reacting mixture chemical exergy and equilibrium concepts.
b. Describe the fundamental principles and applications of direct energy conversion systems.
c. Describe alternative and renewable energy sources and devices used to harness them.
d. Explain emerging national and global energy, water and environmental issues and how these affect politics, economics and society in general.

Course objective (a) seeks to develop a greater understanding of the conventional power scenario. Objective (b) looks at direct energy devices, which cadets have not seen in previous courses, in order to get them out of the box and to introduce highly creative ways to harness energy. Objective (c) reminds students that there are energy potentials in nature that can be tapped into, and echoes the resurging trends towards exploration of renewable energy resources and the development of cost effective devices to harness them. Objective (d) takes the students outside of the realm of textbook engineering, by stressing that real engineering must deal with societal issues. It is also important for the students to realize that energy, food, water and the environment are intimately connected. The actions in one area will affect the others.

To accomplish these goals, the course syllabus used in Spring 2008 is provided in Table 1, and the graded events are noted in Table 2. There are 40 lessons in each semester.

Table 1. Course syllabus for ME472 during Spring 2008.

1	State of World Energy
2	Fuels and Combustion
3	Adiabatic Flame Temperature
4	Chemical Exergy I
5	Chemical Exergy II
6	Chemical Equilibrium
7	Biomass
8	Hydrogen
9	Fuel Cells
10	Exam I
11	Movie – "Who Killed the Electric Car?"
12	Batteries and Electric Vehicles
13	Advanced Power Plants
14	Clean Coal and Carbon Capture
15	Trip – GE Global Research Center
16	Global Warming
17	Solar Energy Fundamentals
18	Solar Heating / Cooling
19	Solar Thermal Power
20	Semiconductors
21	Photovoltaics
22	Nuclear Power
23	Trip – Indian Point Nuclear Power Plant
24	Thermoelectric Power
25	Thermoelectric Cooling
26	Thermionics
27	Magnetohydrodynamics
28	Exam II
29	Wind and Hydropower
30	Ocean Energy (OTEC, Tidal, Current, Salinity)
31	Water Resources
32	Geothermal Energy
33	Cooling and Refrigeration
34	Energy Storage
35	Thermoeconomics
36	Military Energy Solutions
37	Exam III
38	Cadet Presentations I
39	Cadet Presentations II
40	End of Course Review

The course is an elective with a historically small enrollment of around a dozen cadets. Because of this, there is the rare opportunity for group discussions, which is utilized several times during the semester to change the pace and ensure that everyone is heard. It has proven to be an avenue for even the quiet students to speak their mind and express their opinions on a very relevant and timely subject. Many of the topical areas, such as global warming or the use of biofuels has much embedded debate, so students are asked to take opposing sides so that all arguments are heard. As future leaders, they will have to listen to all sides before making decisions. The small group size also accommodates trips that highlight certain topical areas. In 2008, the course toured General Electric's Global Research Center to experience the cutting edge in advanced fossil fuel and alternative energy technologies, and Entergy's Nuclear Power Plant at Indian Point to experience a technology that will soon reemerge in the U.S. with greater strength.

Table 2. Graded events for ME472 during Spring 2008.

Requirement	Point Value	% Grade
3 Exams @200 pts	600	30.0 %
Final Exam	500	25.0 %
Homework	500	25.0 %
Technology Review	200	10.0 %
Geopolitical Review	200	10.0 %
TOTAL	**2000**	**100.0 %**

The course graded events include a Technology Review for the students to research an energy topic of personal interest that was not covered during the course in great detail. A presentation is included so that the entire course profits from it. The Geopolitical Review includes a paper and presentation to extend the energy focus beyond the DoD and U.S. Each student researches the energy status, concerns and strategies of a different country and shares findings with the course. The goal is to educate the future leaders to also be global thinkers, and to emphasize how energy issues are so dominant in the actions of countries and peoples. The list of countries selected in Spring 2008 are listed in Table 3.

Table 3. Countries selected by students during Spring 2008 for the Geopolitical Review.

Brazil	China	Germany	India	Russia	UAE
Canada	France	Iceland	Norway	Saudi Arabia	Venezuela

Feedback is solicited from cadets informally during the semester, and formally at the end of the semester through an Academy-wide online system. At the time of writing, the Spring 2008 semester was still in session, and so results from Spring 2007 are presented in Figures 3-6, showing only those questions relevant to this paper. Feedback is provided for questions on hierarchical levels including the **Academy**, Civil and Mechanical Engineering **Department**, Mechanical Engineering **Program**, and the Energy Conversion Systems **Course**. The questions are answered on a scale of 1-5, with 5 indicating strong agreement. An overall satisfaction is evident from the Figures, and the course earned marks generally higher than the Program and the Department.

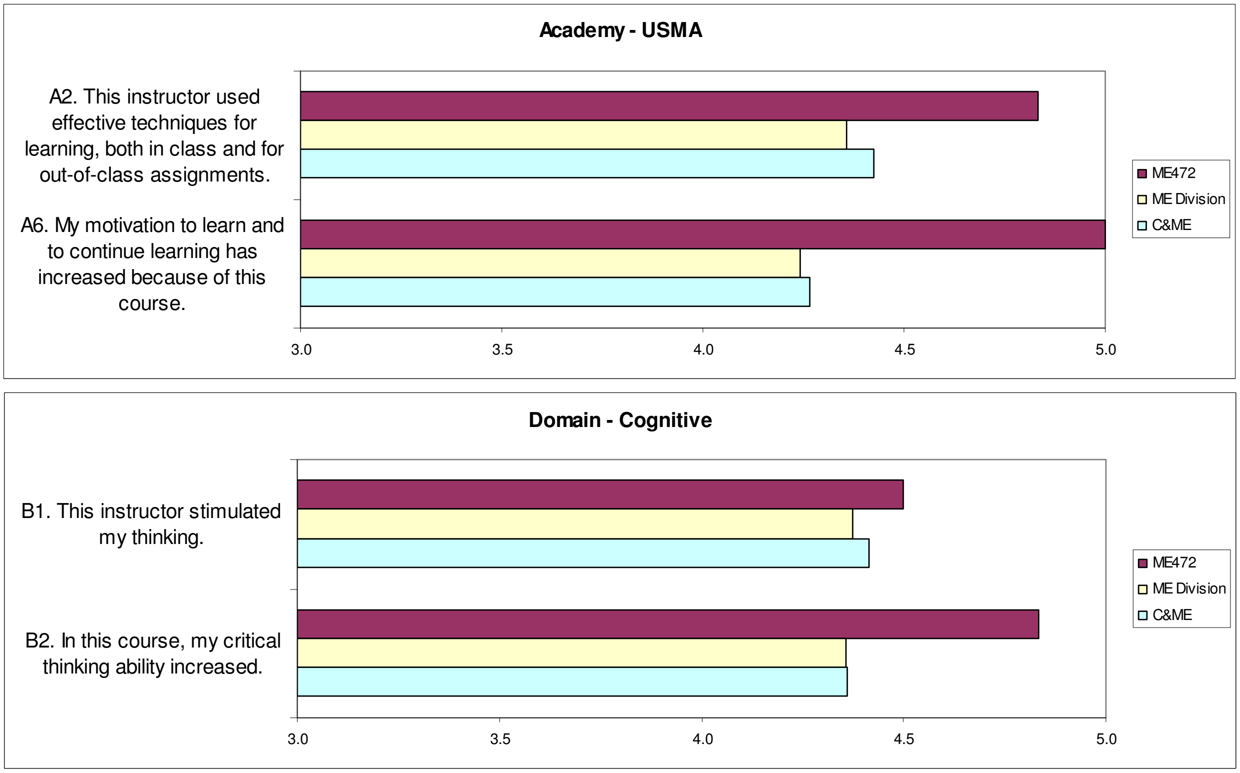

Figure 3 Course end feedback on relevant Academy level questions for Spring 2007.

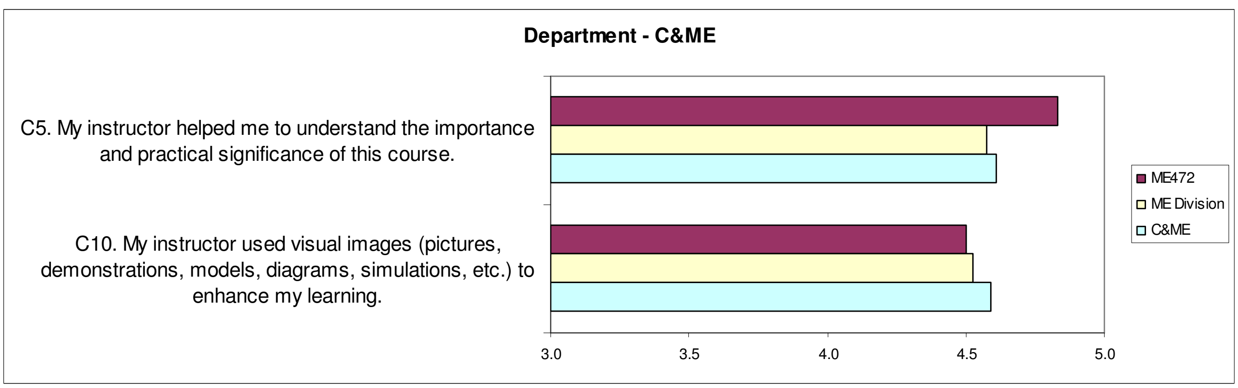

Figure 4 Course end feedback on relevant Department level questions for Spring 2007.

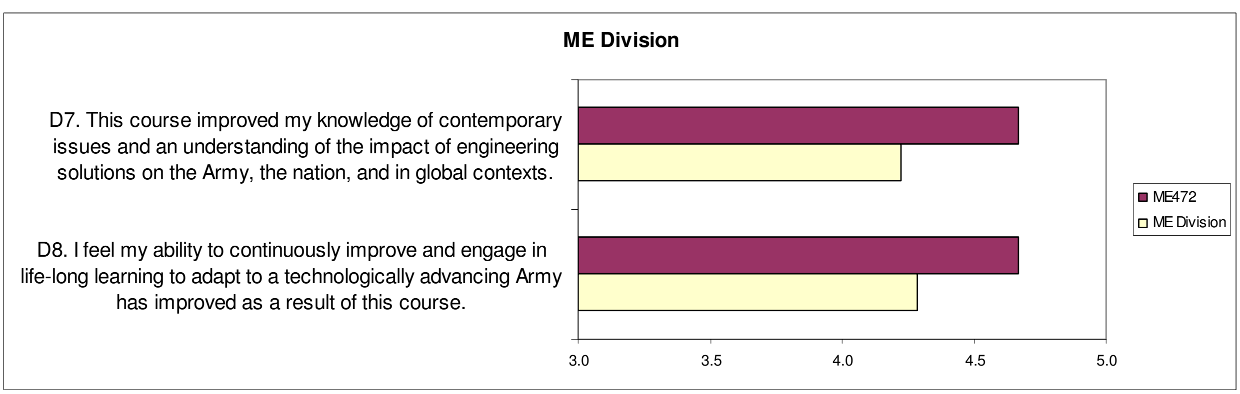

Figure 5 Course end feedback on relevant Program level questions for Spring 2007.

All of the Course level questions are presented in Figure 6, which are intended to test the success of meeting the course objectives. Questions E1-E3 are based on a technical understanding of the course material, while questions E4 and E5 are based on non-technical objectives. These explore whether the cadets are leaving this course with a greater understanding of and appreciation for energy in a global context. Although the course had only 8 students in Spring 2007, it brings the greatest satisfaction that these two questions in particular received the maximum rating.

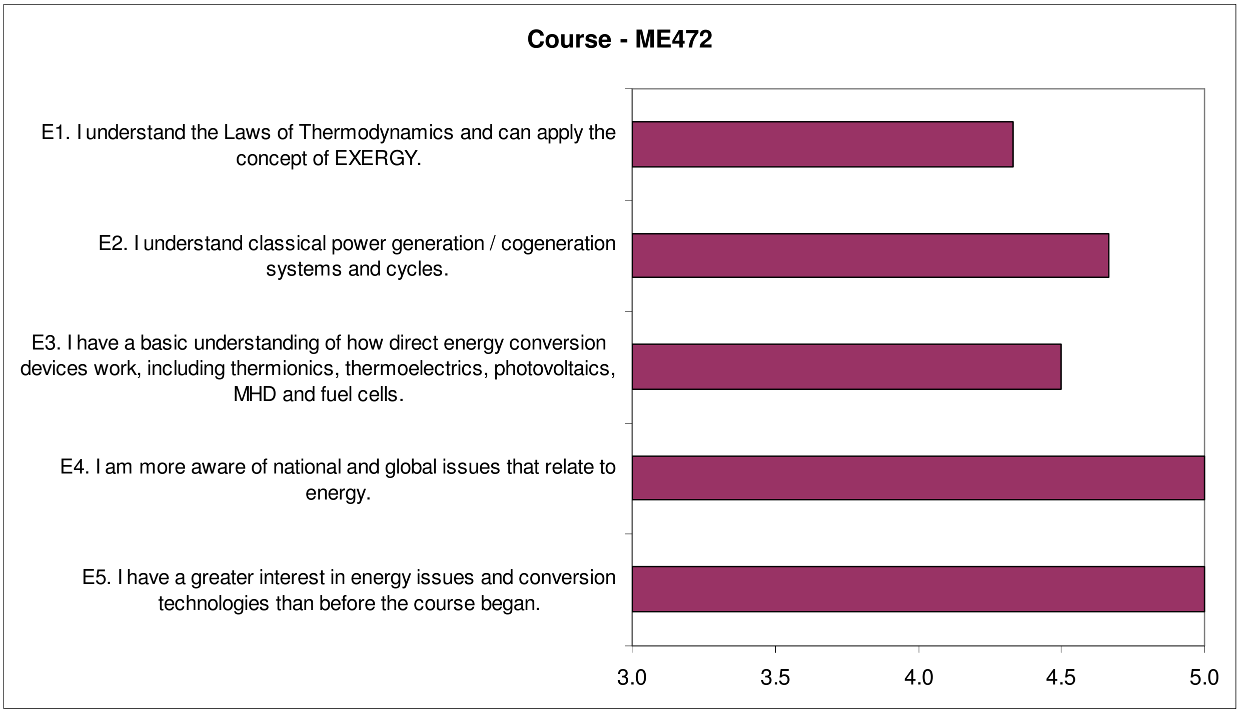

Figure 6 Course end feedback on relevant Course level questions for Spring 2007.

In addition to numerical feedback, the students are prompted in these anonymous surveys to provide general comments and suggestions. Many comments showed that the cadets found value in the course, which echoes the marks in the previous Figures. One comment that captures the intent of the course is provided here from Spring 2007.

> *This class kind of inspires you to learn more, because you realize the engineering world is bigger than just turbines and pumps. And it's more important than just making things more efficient. Engineers are going to play a huge role in solving the problems we'll see in the next 50 years and I want to help.*

Suggestions were critical yet constructive, which are both desirable. A common suggestion was to have a comprehensive course textbook, although none exists that merits the cost of purchase. Currently the course makes use of a textbook from their previous thermodynamics course, which is supplemented by readings selected from online resources and publications. This may likely remain the best option because of the nature of the course material. Technology and societal issues related to energy are rapidly changing, so a textbook is only worthwhile to cover fundamental bedrock principles. The authors are currently preparing such a textbook.

Conclusion

The evolution of a course on Energy Conversion Systems at the United States Military Academy has been presented. For over 20 years, the course material has historically been an indicator of the global energy focus of the era, shifting from alternative energy resources to fossil fuels and now once again to alternatives. At every time, the goal has been to educate, train and inspire the cadets enrolled to become future military and civilian leaders that are properly rehearsed on matters of energy.

Acknowledgements

The views expressed herein are those of the authors and do not purport to reflect the position of the United States Military Academy, the Department of the Army, or the Department of Defense.

References

1. Energy Information Agency, U.S. Department of Energy, *Annual Energy Review*, 2007.
2 Energy Ideas, http://www.energyideas.org/pages/default.cfm?o=h,g,ps&c=z,z,126
3. U.S. Department of Energy, *DOE Annual Energy Review*, 2005.
4. Defense Energy Support Center, U.S. Department of Defense, *DESC Fact Book*, 2005.
5. Nygren, K.P., Massie, D.D., and Kern, P.J., *Army Energy Strategy for the End of Cheap Oil*, Proceedings of the 25th Army Science Conference, Orlando, FL, 2006.
6. National Academy of Sciences, *Meeting the Energy Needs of Future Warriors*, 2004.
7. U.S. Department of Defense, Wearable Power Competition, http://www.dod.mil/ddre/prize/topic.html, 2007.
8. USMA Office of the Dean, *Educating Future Army Officers for a Changing World*, West Point, NY: U.S. Military Academy, 2007.
9. Bailey, M., Arnas, A.Ö., Potter, R., and Samples, J.W., *The 20 Year Evolution of an Energy Conversion Course at the United States Military Academy.* Energy Conversion and Management, 2004. **45**: p. 495-509.