Renewable Energy: An Interdisciplinary Problem Solving Course

Alan H McGowan
Department of Natural Sciences and Mathematics
Eugene Lang College The New School for Liberal Arts
65 West 11th Street, New York, NY 10025, USA

ABSTRACT

This paper describes a new intermediate course given in the Environmental Studies Program at The New School. It incorporates research activities by the class as a whole, in the process of which the class learns a great deal about the science and technology of non-fossil fuels, their promises and difficulties. Since ameliorating human influenced global climate change, educating and training students in the skills necessary to accomplish the necessary transition is essential. The course embodies a class project on which everyone works, entitled "Fueling America," whose purpose is to determine what technologies deployed in what manner and in what quantities can eliminate the use of fossil fuels in the United States by a date certain. Knowing that it was impossible, we nevertheless chose an early date, 2030, so that it seemed reachable for the students. The project resulted in a technical paper, which included an economic analysis. In addition to alternative energy technologies, the technologies of energy efficiencies were also included.

Keywords: fossil fuels, solar energy, energy efficiency, climate change, tidal energy, biomass, wind

INTRODUCTION

The Renewable Energy course in Environmental Studies was comprised of students from Environmental Studies, Integrated Science, and Urban Studies programs. A prerequisite for the course was an introductory one, Energy and Sustainability, which I have taught for six years. [1] That course laid the basis of understanding energy from a physics and chemical point of view, considered the first two laws of thermodynamics, and assured the students had certain calculation skills necessary for the work in the course.

The enthusiasm for the course was very high, due both to the commitment of the particular students in the course for building a more sustainable society, and because of the joint class project, in which every student participated. As one student said at the presentation of the final report to a group of students and teachers: "It was great because everyone worked together, and there was not the usual competition for grades that you find in many courses." Of course grades were given, but based primarily on class discussions and individual presentations from the reading. Students met out of class, on their own, to discuss their work, and one student started a blog for the course, which I had nothing to do with. It was fundamentally a student centered course, and it showed the benefits of constructing a course in this manner.

Energy is fundamental to our lives, and students learn how difficult it is to wean ourselves off of the intensive use of energy which characterizes modern economies. Although the date we chose to be free of fossil fuels, was totally unrealistic, the date was chosen as a forcing mechanism, so that we could really face the problems of a fossil fuel free society. Students were eager to adopt an early date, because they were learning that global climate change was occurring more quickly than experts had originally predicted. The lack of political action on combatting climate change also fueled their eagerness.

THE COURSE

The course started with consideration of basic concepts; we used a text for basic understanding of different energy concepts. The class was run as a true seminar; students made presentations from the text [2] as well as from supplemental reading posted on the on-line service we use, Blackboard. As well, students were required to search for their own supplemental material for the topic on which they were presenting. Although this meant a good deal more time preparing for each class hour than is usual, students ended up being very enthusiastic about this aspect. They felt as though they were being treated as serious researchers, which they were.

Although this part of the course went on for some time, after a few weeks the students felt they were ready to tackle the main project, "Fueling America." To be sure, in the beginning of this process they did not realize how hard a job it was going to be; one student said that one value of the class was to demonstrate how hard the job was, both of removing American dependence on fossil fuels and also finding adequate information about each technology. She said: "I used to say this is simple, just go to solar power. Now I think this is hard!"

There followed intense discussion of the various technical possibilities, after which the class discussed how to proceed. They decided that one person - there were only six students in the class - would deal with one technology or technique, and that each student, in consultation with others, could choose what he or she wanted, making sure there were no duplications. With such a small number of students, that meant that some promising technologies would not be covered, and we would have to acknowledge that in our report. In the end, one of the most promising technologies, the many ways of using biomass, was not analyzed in the report. Although this is obviously a significant deficiency, the class decided, and I agreed, that it was more important in terms of student enthusiasm to let students work on a technology of their own choice. This would not have been an issue with a larger class, and there

is, of course, another way to proceed, to insist that the most promising technologies be considered. This is a pedagogical issue, and I am sure there are many who would have chosen an alternative scenario.

The six areas that were considered were: wind, tidal power, solar photovoltaics, nuclear, efficiency in buildings, and efficiencies in transportation. For both building and energy efficiencies, increasing the efficiency of buildings and automobiles, for example, were considered, as well as increasing the efficiency of the system, more mass transit, for example, and reorganizing where people live - more city and less suburban living, for one. The students working on efficiencies of the building and transportation sectors worked closely together, since housing patterns have much to do with automobile use and other transportation issues.

To coordinate the effort, a Google Doc was created, so that each student could see each other's work and comment on it. Each student had to report the basics about the technology, including its current state of development. Also necessary to include were cost - both current and projected future cost - land mass, and any environmental concerns about the manufacture or deployment of the technology. A portion of each class was devoted to a discussion of the data posted; as the end of the project neared, practically all class time was spent on this process.

Each technology or technique posed its difficulties, which the students soon came to realize. Wind, for example, was a very attractive option, until the student involved had to calculate the land mass necessary. Although there are a number of sites in the United States which are capable of supplying electricity from wind, the land mass they must occupy is significant. A similar picture is found in solar photovoltaics; the density of the energy from the sun, though large in absolute terms, is simply not high enough to sustain, for example, a solar car, at least one that has normal dimensions and weight. Even a small car would need a huge collector on top to propel it at any speed.

The basic problem, of course, is that with the exception of tidal power and geothermal, all non-fossil fuel energy comes from the sun. The power density of the sun is about 1 kW per square meter; the area of the United States is 9.8 x 10 to the twelfth power meters. On average, we can only obtain about 6 or 7 hours of sun per day; that gives us 7 kWh (kilowatt hours) per day per square meter. Assuming the 15% efficiency of current solar photovoltaic cells (redo calculations). [3]

In 2009, the United States used 94.6 Quads, or quadrillion BTUs per year, which is what the class used as our benchmark, even though we knew that energy use would increase every year as it has for the last hundred, though energy use per capita in the United States has remained roughly the same or even declined in the last few years. [4] It gave us a target to shoot for.

Nuclear power, to nobody's surprise, was the most controversial. Despite many arguments in the class, it was determined - I must admit, with some urging from me - that it had to be considered. After all the numbers came in, we and society could decide not to use it, but that it ought to be considered. It led to a very interesting discussion of the trade-offs that one inevitably faces in considering these issues. Although it is hard to find totally unbiased reports on the relative benefits of nuclear vs. coal, there is interesting information that can be found. [5] Almost everyone agrees that under regular running conditions, coal causes more deaths per unit of energy produced by orders of magnitude over nuclear. However, nuclear power makes many people nervous, partly because of its association with the atomic bomb, and partly because of the potential for very serious radioactive contamination. The poster child for this is Chernobyl, of course, Fukushima, both of which caused great damage and deaths; Three Mile Island while very serious, caused few if any deaths.

Thus, the decision ultimately depends on how serious one takes global climate change and environmental pollution. Everyone in the class came into it with a strong feeling that these were very important issues, and that both global warming and environmental pollution were serious threats. Particularly when the students realized how difficult it was to completely eliminate fossil fuels from the energy picture, and that nuclear energy could be necessary to fill in where solar and other alternative energy forms might fall short, they started to face the tough issues. More about this later, but one of the real benefits of this course was showing them that tough choices had to be made.

Tidal energy turned out to be an interesting choice. As I said, students could choose a source that was of interest to them. This continued to be true, even after the student who chose tidal quickly found out that tidal energy at most could supply one or two percent of our total energy supply. The class agreed that this should remain in the final report - even though if this were a realistic attempt to wean the nation off of fossil fuels, one would quickly abandon this and go on to something else - since there is a lot of talk in some circles about the benefits of tidal power and it was useful to make the point that some alternative energy sources are just not going to play a big role.

The class also considered, because it discovered that it had to, some rather radical changes in societal organization. The urban studies student, who was studying building efficiencies, included a large section on the energy wasting facet of suburban living. Working very closely with the student studying transportation, he (there were five men in the class, one woman) pointed out that the very design of suburban homes and their layouts required a great deal of energy to heat and cool, since they were all separate units, and also required cars and much driving, since many suburban layouts foreclose any notion of an adequate public transportation system, although many suburban areas have some kind of bus system. The difficulties of changing the system were obviously seen as very difficult, pointing out yet again what an enormous task we face.

The students finished with a report, detailing their research and their conclusions, and made the presentation previously referred to. The current plan is to use this report as the

starting point for the next class - it is currently planned to offer this course every other year - and perhaps in three or four iterations have a complete report in publishable form.

BENEFITS

Although many of the claims I make about the benefits of this course are anecdotal, there is a good deal of research pointing to the value of this way of conducting a class. [6-15] We know that students learn best when they are engaged, and we know that creating a learning community in the classroom is important to retaining knowledge. All of these benefits have accrued to the students in this class. Student evaluations, both at mid-term and at the end of the class, were very high, with every student saying they would highly recommend the course to their friends.

But, of course, student satisfaction is not the only measure of success, although I think it is a necessary condition for success. What we really want to know, we cannot measure at this time; that is, what the students will remember about and what they will remember from this course in ten or even twenty years after graduation. However, there is research, in the references above, that tells us students are much more likely to remember from this kind of course than a traditional lecture or even seminar course. Time will tell.

CONCLUSIONS

In addition to the benefits, there are costs and risks to doing such a course. Its success depends greatly on the type of student who enrolls. One student who does not pull his or her own weight, or is difficult in class discussions, or who disrupts the class in one of any number of ways, will prevent the establishment of the good will that is necessary for the course to succeed. The students really have to be willing to help each other, and to contribute to the course in many ways. As noted above, one student started a blog, with which I had nothing to do; yet another posted results of the research on a web page she kept on sustainable development.

The students also need to come to the course with a minimum of calculation and research skills. Students at the university in which I teach are traditionally math-phobic - mirroring the large number of students nation wide who suffer thus - and some time had to be spent in class going over basic computational and especially algebra skills. [13] I would expect in other, more technically oriented schools, this might not be such a problem, but students certainly need to know how to perform elementary mathematical operations, including conversions of one unit to another and other such calculations.

Because a prerequisite was the Energy and Sustainability course - all truth be told not every student had actually taken the course, but were considered sufficiently skilled that they could take this course - they were well versed in the issue of global climate change, and so the motivation to switch to alternative fuels was strong. [16] This motivation was key in impelling to do the rather large amount of work necessary.

It was difficult to fit everything into the one hour forty minute class, twice a week for fifteen weeks. Time after time we would run out of time, and the students would be required to determine things on their own. Their work load was heavy; though remarkably nobody complained about it, they regularly said it was the hardest course they were taking that semester, and required the most work.

The lack of time led to another problem. Although sustainability contains within it issues of social justice - some solutions for energy efficiency, rising prices dramatically, for example, affect poor people much more than the well-to-do - and there is a large literature that speaks to such issues, there was little time to consider such questions. [17-24] I would hope to be able to find time in future editions of the course to deal with such questions, for in my mind they are key.

Finally, there is a good deal of research which is necessary to determine the effect of courses taught in this way. With such a small class, and with no control group, it was impossible to do a true assessment of the course, but such research is necessary. We think we know what effective teaching is, but in fact there are many surprises contained herein. It is my hope that by teaching such courses and by talking about them in conferences like this, we will be able to stimulate the necessary research.

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