"Hands on" Energy Curriculum At Stanford University

Eric Selmon, Mercer Management Consulting
Stephen H. Schneider, Ph.D.
Department of Biological Sciences, Stanford University

At universities and colleges across the country, environmental science programs are increasing in number and size as society attempts to learn more about and craft policies to deal with environmental issues. The question "What should we do?" grows more urgent. Many academics now realize this is a question deserving serious consideration, not only in research, but in undergraduate and graduate education.

One answer is relatively simple: reduce greenhouse gas emissions by increasing energy efficiency and the use of renewable energy sources. While there are many concerns, primarily economic, about renewable energy sources, few voice objections to enhancing energy efficiency, at least, in theory. Despite the possibilities, energy use continues to grow and efficiency only increases slowly. Are the technologists fundamentally wrong, or are there non-technical barriers to achieving efficiency potentials in the real world?

The next question is, "Given the economic and environmental benefits of replacing inefficient equipment with more energy efficient technologies, why are they not being implemented at a faster pace?" While official assessments tend to focus on technical possibilities, several answers to the implementation question have been identified by Stanford University students who pursued projects aimed at understanding this practical question. Their conclusions: sub-optimization, ignorance, special interests and institutional barriers. As educators, how can we deal with these problems in the classroom, i.e., how can we extend the classroom into the "real world?"

This article summarizes the rationale for a year-long course which could be the core or the culmination of an energy/environment program. This course would combine theory and practice, taking students from beginning to end of an energy efficiency project at their university or college, from design to implementation, including selling the project to local decision makers. This article will describe our experiences at Stanford which led to the development of a prototype of such a course. (for a more prosaic treatment of the experiences of Stanford students see Schneider, S.H. and E. Selmon, 1996). A number of courses at Stanford in various programs focus on energy, but they are primarily theoretical or technological. In devising an energy course to address implementation barriers, we initially focused solely on projects, assuming the students had the necessary background of engineering and economics to tackle them and that the bulk of the learning could be done in the field. By letting students choose their own projects and work on them to completion, they must put their prior knowledge to use in ways most had not previously experienced in academic classes. Outside of the class, they start from square one.

First they must choose the specific situation on which they want to work. If the project is not interesting to the students, they will not do a thorough job—a good reason to let them choose their own projects. But even this is no guarantee of success. For example, one group in our course tried to assess the potential for retrofitting a standing 300 watt halogen lamp, commonly used in the dorms by students at most schools, with compact fluorescents. One of the students was only interested in the design of the retrofit and did not participate in the other aspects of the project. This caused tensions that we believe degraded their collective final presentation and paper.

Another problem is that once the conceptual and field parts of the project are done, putting the work down on paper may seem anticlimactic, resulting in a sloppy final paper. It is difficult to convince a decision maker to implement projects when the reports are slipshod, i.e., without good quantitative technical and economic analysis and clear exposition.

Once a group has decided on a situation to study they must then attempt to first identify and then answer the questions that lie behind a good project. What are the problems being addressed and at what scales of technology and society? From whose perspectives are they problems? Does the problem result from an institutional barrier or from the lack of information, time or money? Is it a problem of technology or inappropriate incentives to managers or consumers? What are potential solutions? Are they global or only problem-specific? Is the solution a paradigm shift or a quick-fix? Can it be applied at other scales or to other problems? Students rarely face these questions in a traditional classroom setting.

They need guidance from the faculty, visiting lecturers with "real world" experience, and many examples—including the projects of their fellow students.

However, energy efficiency issues require not only "real world" projects, but classroom teaching and context, as well, to gain the theoretical or technical background necessary to place the projects within the proper framework while working on it. We eventually settled on a format that combined student projects with many guest lecturers. The lecture topics ranged from "institutional barriers to energy conservation" to "energy efficient lighting technologies" to "energy efficiency in the developing world." (See Appendix A—complete list of lectures) The projects were, as we explained earlier, left up to the groups to find and do. This resulted in a combination where students, while addressing similar issues themselves, heard many examples of actual problems faced in implementing energy efficiency and ways in which they were (or were not) overcome. They were able to learn from and build on the experiences shared by the lecturers and make contacts with professionals who could advise them in their work. Moreover, the classroom discussions allowed them to learn from each other, as well—a critical factor in their enthusiasm.

Generally, the students' projects were local both for logistical convenience and because that is the scale at which most decisions affecting energy efficiency are made. Therefore, there were specifics to our curriculum which might not be replicable elsewhere. Nevertheless, the general issues the students faced should be similar around the country.

STANFORD AS A MICROCOSM

When we became involved in energy efficiency at Stanford, we started along two different paths. Schneider took the academic route, setting up a special project course, ES10x, for students interested in studying energy efficiency at Stanford. The projects these freshmen and sophomores worked on ranged from a study of the lighting in the student union, where incandescents and high-pressure sodium lamps are used, to the possibility of using solar water heating in one of the dorms. One group studying the lighting in one of the dormitories found that Housing and Food Services, the department in charge of the dorms, avoided the most efficient (and higher quality) lighting option in order to achieve a "homey" look. The student group conducted a survey of students living in one of the dorms and found that residents unanimously preferred lighting quality and energy efficiency to the "homey" look.

An alternative route was taken by Selmon. He, along with a group of students interested in energy efficiency, began meeting in the winter of 1992 with Professor Gil Masters of the Civil Engineering department to discuss energy use at Stanford. At first they hoped to address energy use for all of Stanford, but eventually decided to focus on one building, the Terman Engineering Center, which houses the School of Engineering.

The group worked through the winter and spring quarters of 1992 to design a lighting retrofit for Terman. This involved extensive metering of energy use to help determine lighting's share of the electricity load, walk-throughs at all hours of the day to determine the hours of use, and surveys of the occupants to determine their concerns and needs relating to lighting. The final design was submitted with a paper to Scott Gould, the Stanford Energy Engineer, and Mike McKnight, the manager of the Utilities Division at the time.

Unlike the projects in Schneider's course above, the project did not end at this point, however, because Gould expressed interest in the work. He was one of the few staff members at the time who not only held a position with energy conservation responsibilities, but who also had a genuine interest in energy efficiency and in student input.

The following fall, the team did more detailed counts of the fixtures and analyses of the costs and savings of the project. They also examined a number of options for the various areas of the building, going so far as to install one option in an office to get responses from the occupants of the building. This not only allowed them to measure the results, but helped to build support among the building's occupants and probably avoided many complaints after the project was completed.

By May of 1993 they had completed a proposal which retrofitted every fixture in the building, including the offices, classrooms, laboratories and the library. Moreover, they had conducted extensive studies to determine the hours of use and the electric load attributable to lighting. As a final step in convincing the University to implement the project, they did all of the work necessary to put the project out for bid, including writing up the specifications for the contractor. After the project was complete, the two students performed analyses of the energy use to verify the savings. The results were very close to the original estimates, 21% actual reduction in energy use versus a 23% prediction.

This project took five quarters, or, approximately, three semesters, to bring to the point where the University implemented it. It involved extensive cooperation with University staff. However, the result was extremely successful. The University got a ready-to-implement project which saved $27,000 per year with an initial cost of $114,000 (nearly a 4-year payback, a considerably better return on investment than Stanford's endowment) and favorable publicity through articles about the project in *The Stanford Daily*, the student newspaper, and *Energy User News*, a trade publication. The students gained valuable experience in identifying and addressing barriers to energy efficiency and presented a paper on the project at the Association of Energy Engineers annual convention in Atlanta.

Furthermore, student involvement made the project more successful in reducing energy use. The project was comprehensive, retrofitting every fixture and utilizing various control technologies, and the savings were verified. The students had the time to examine all aspects of the project and package all of the parts as one project with a single rate of return.

While the Terman lighting retrofit was near ideal for student energy efficiency projects, there are some aspects which make it difficult to reproduce in an ongoing class. Most importantly is the time the project took to complete. One-and-a-half years is a very long time for any student to devote to a class. However, much of the time involved with this project was spent learning about the technologies available. Ideally, students would have a background in the technologies from previous classes.

After the Terman project was completed, Schneider and Selmon joined forces and began to talk about institutionalizing energy efficiency teaching and action at Stanford. We collaborated on a second year of ES10x in the spring of 1994. This time the student volunteers built on some of the experiences of the previous year. There were three projects: one on university housing, one studied the organization and accounting of the university, and a final group attempted to continue the work on the student union, but failing that re-focused on the music department's building.

All of the students learned lessons that seemed generally true around the campus and probably around the world, as well. The split incentives whereby each management group optimizes its own local situation, but creates a clear suboptimization for the organization as a whole, is a typical problem. Accounting situations where people who pay the electric bills are not the same people who pay for efficiency investments—both from fixed budgets—is a prime example.

At the root of all these difficulties is the question of scale. The price of doing business does not usually reflect the costs of global warming, ozone depletion, biodiversity loss and other problems of that scope because they can occur at different scales and in different political jurisdictions than the activities that cause them. Not only is local efficiency more valued than global efficiency, but "political efficiency" is of the utmost value because many small groups might no longer be able to pursue their traditional activities unimpeded once the damage they might cause at the global scale becomes known and valued.

After our experience with the second year of ES10x volunteer students, we decided that a more formal and higher level course should be tried. We hoped to integrate our experiences from ES10x and the Terman project into a course that would teach students about the barriers to energy efficiency, both in class and through their projects, and would get some aspects of their proposals and recommendations implemented. We wanted the students to focus on local energy efficiency projects while still studying and addressing issues of scale. This led to the development of the prototype course that was taught in the spring of 1995, Earth Systems (ES) 179, *Energy Systems: Achieving Energy Efficiency in the Real World*. This course was also cross-listed as Civil Engineering (CE) 179, an action which encouraged a number of engineering students to enroll.

THE COURSE

The course intended to not only teach energy efficiency in the classroom, but to give students "real world" experience. To this end we attempted to use guest lectures from various parts of the corporate world. (See Appendix A for the lectures and lecturers).Moreover, we made the projects count for most of the students' grades.

The students generally responded favorably to the lectures. Some saw the lecture on lighting as repetitive because it covered technologies most of the students understood; however, other students really enjoyed that lecture because it addressed many of the specific problems the lecturer had faced in doing retrofits, from initial barriers to selling a project to problems that arise during or after the project is implemented.

A number of the major lessons we hoped to teach in the class involved the interpersonal and communications skills necessary for, not only designing projects, but implementing them in spite of sometimes initially hostile reactions. Therefore, we encouraged students to work in groups and to practice these skills first by working with each other.

Furthermore, we emphasized the importance of contacts with the people in decision making roles for the situation being addressed. To this end we arranged special lunches for 3 or 4 students at a time with Schneider, Selmon and the guest lecturer (if any). This allowed personal contacts and *esprit de corp* to develop that helped students with team projects. From our previous experiences, we believed the teams and the connections were keys to successful projects.

In addition to assisting students in developing their ideas, we also tried to aid students, based on our experiences, in designing and implementing their projects. Selmon met with each group two or three times throughout the quarter, as well as other informal talks after class, to discuss their projects. These discussions were not just a chance for students to describe their progress, but also an opportunity for them to get some help in addressing various issues and barriers that arose.

The students were given great freedom in choosing their project topics. Our only requirements were that they focused on energy efficiency and that the final recommendations were readily implementable (in principle, at least) at the local level. We emphasized that we were not grading projects on their success at implementation because one academic quarter is rarely long enough to implement a project and because the students had no direct managerial authority. We were more interested in the overall process and the formal written and oral presentation of the project.

How did the teams answer the questions we raised earlier in this article? Did they analyze the situation and their recommendations thoroughly and quantitatively? Did they examine how their problems and solutions might change at different scales? Did their presentation convince the class of the importance of the problem and the feasibility of the proposed solutions? Did the final paper incorporate the issues and concerns brought up by the class during the presentations? Was the work careful and well-presented, showing respect for the intended audiences, i.e., the decision-makers?

The students created a diverse array of projects. One group looked at the lighting in a local private high school, proposed a retrofit and wrote a manual for building occupants, be they office workers or students, to help them design and propose their own retrofits.

Another group studied computer use at Stanford, and set out to correct misinformation most people have about using their computers, such as how often they can turn the computers off, the energy use of monitors and screen savers. The students also hoped to determine how effective providing correct information would be in reducing energy use by computers. They first had to find out the correct information about computer energy use, the ability to turn computers on and off without damaging them, and the energy use of monitors. They then needed to determine how to measure computer use without interfering with the user (i.e., students in the dorms). They eventually settled on using a program which records how long a computer is on and a temperature sensor to measure monitor use.

The group decided to focus on student computer use. They tried to get as many students as possible in a single dorm to participate. They had to convince the other students that their study would not harm the computers in any way, particularly with viruses, and would not interfere with their work. They circulated a clever and colorful flyer in the dorms. The group then let their equipment take readings for a week before they gave dorm residents information about computer energy use and better ways to use their computers, such as turning off the monitors during short idle periods and the computers themselves for longer idle periods. They then waited another week before going to gather the data. They found a significant drop in computer use: the computers were on about 18 hours less per week after the educational effort. Around a campus with thousands of computers, some of which use a few hundred watts of power, the energy savings could be large.

Using this information they put together a number of recommendations for the university. These included teaching about computer energy use in the introductory computer classes for students and staff, sending information with university mailings, and giving a sheet of information to everyone buying computers at the Stanford Bookstore.

The success of the prototype course has been to introduce the students to many of the factors preventing energy-efficiency implementation in the real world. The lectures gave the students some contextual background, followed by actual examples from other people's experiences.

PROJECT IMPLEMENTATION IS VALUABLE, BUT DIFFICULT TO ACHIEVE

However, some projects were never fully implemented because the students no longer had a formal setting—the class—to keep them motivated and focused. In the Terman project, a large part of the experience was in designing a more detailed proposal and ironing out the flaws before it went to bid. There was also the interaction with the building occupants in choosing an alternative which worked for them. Finally, there was the satisfaction of having implemented a major energy efficiency project, particularly given the monitoring program after implementation.

To improve the implementation phase for future classes we propose a year-long course. (Perhaps with a second year follow-up seminar) The first quarter, or semester, would include guest lecturers to discuss their experiences. The students would work on choosing and writing a draft of their proposal. In *Energy Systems*, the students' project papers focused on defining the problem, contacting the key personnel, identifying and quantitatively analyzing alternative solutions and recommending one.

The rest of the year would be spent working with the necessary staff and decision-makers to refine the project and implement it. This stage would require close involvement of some of the staff involved with the project. They would be necessary to help identify flaws in the proposal and correct them, and to support the project through the decision-making process in order to implement it. This would probably work best with on-campus projects because students and faculty can then build an ongoing working relationship with staff and have more influence in implementing the projects.

INTERACTIONS WITH PROFESSIONAL STAFF

Throughout all of our experiences with energy-efficiency issues at Stanford we have found that the relationships with the professional staff can not only aid the success of a project, but can also greatly enhance the learning experience. Developing good working relationships with the staff the students will be working with is probably the single most important aspect of making a successful energy curriculum focused on implementing solutions to actual situations.

In working on the Terman project, Gould was invaluable. He put Selmon in touch with everyone he needed to talk to. He reviewed every version of the proposal. He made sure Selmon knew about everything that needed to get done for implementation. He also helped with verification by giving Selmon access to the necessary equipment and data.

That relationship also helped the students in the second year of ES10x and of *Energy Systems* because Gould and his colleagues were willing to give the time to talk to the students. He put them in touch with other staff at Stanford who were better able to help with specific issues.

In talking with the technical staff, we found that many enjoyed working with students. These people were willing to put in extra time to help the students. The staff enjoyed being a direct part of the educational mission of Stanford. Furthermore, many of them were independently interested in energy efficiency, and the students could help them further their interests.

However, some staff people see students as inconsistent and unwilling to follow through. Students would often work on projects for only three months, the length of an academic quarter, or ignore the project during mid-terms and finals. Also, when students start work on a project they often need training, which the staff could see as a waste of time if they only get three months' work out of the students. These staff people need to be convinced of the commitment of the students to be willing to work with them. They also need to be warned in advance about the academic schedule, particularly the dates of mid-terms, finals, and semester breaks, so they can adjust the schedule of the project.

Connections with the energy-related staff must be maintained. They must be long-term contacts to make them work. The ideal relationship would be to have students doing energy-efficiency projects that the staff do not have time to do or that they were not aware of, and having the staff assist the students in bringing the projects to fruition. Some of these projects could last longer than a single year, with staff helping to provide continuity for new students, perhaps by showing them where the previous ones left off. This requires a long-term relationship between the faculty, the students and the staff.

SUSTAINING THE ENERGY SYSTEMS APPROACH

Margaret Mead once outlined three things necessary to make a non-traditional program work: a charismatic leader, enthusiastic young workers, and a benefactor willing to fund the enterprise. The energy curriculum proposed certainly qualifies as non-traditional. The efforts to date have been fairly successful pedagogically because they have had enough of the three ingredients Mead identified. But sustaining an energy systems approach that includes a significant "real world" component will require maintaining the organization and commitment on the part of students, faculty, staff and administration. We are in the midst of working to transcend these constraints and institutionalize our model at Stanford—although it is not yet clear whether this will emerge from the energy track recently created within the Earth Systems program, become part of the environmental engineering curriculum or some combination of these and other administrative arrangements.

But Stanford is not a special case. Appropriate faculty, staff and administrators to fashion an institutionally sustainable energy systems program will vary widely, but can be assembled at many other schools and in many countries. We hope our examples and suggestions here will encourage others to, in their own institutional context, extend the model and provide their students the opportunity to learn, make a difference, and save their institutions money, all at the same time. We look forward to hearing of these experiences.

ABOUT THE AUTHORS

Stephen H. Schneider, Ph.D., is a professor in the Department of Biological Sciences and a Senior Fellow at the Institute for International Studies at Stanford University. In 1992 he received a MacArthur Fellowship for his ability to integrate and interpret the results of global climate research through public lectures, seminars, classroom teaching, environmental assessment committees, media appearances, Congressional testimony, and research collaboration with colleagues. He also received, in 1991, the American Association for the Advancement of Science/Westinghouse Award for Public Understanding of Science and Technology. He is author of *The Genesis Strategy: Climate and Global Survival; The Coevolution of Climate and Life; Global Warming: Are We Entering the Greenhouse Century?; Laboratory Earth: The Planetary Gamble We Can't Afford to Lose* and over 200 scientific papers, reviews and editorials.

Eric Selmon is a research analyst with Mercer Management Consulting, a strategic consulting firm in New York. He received his M.S. in engineering (1995) and his B.S. in earth systems (1994) from Stanford University. The focus of his studies has been energy and the environment, with an emphasis on energy management implementation. He also studied the role of business in environmental and energy issues.

Appendix A: List of Lectures for Earth Systems 179, Spring 1995

Lecture	Lecturer
Course Overview and Global Context: Population, Resources and the Environmental Debate	Stephen H. Schneider, Biological Sciences and the Institute for International Studies, Stanford University
Barriers to Conservation: Real World Examples	Danielle Dowers and Doug Johnson, City of San Francisco, Bureau of Energy Conservation
Energy and Economics: A Systems Analysis	Jim Sweeney, Engineering Economics Systems, Stanford Univ.
Energy and Society: History, Regulations, Demand-Side Management, Industry Structure	Mason Willrich, Former CEO, PG&E Enterprises
Alternative Energy Sources	Tom Hoff, Pacific Energy Group
Energy Efficient End-Uses: Lighting	Matt Tracy, T. Marshall Associates
Energy Efficient End-Uses: HVAC	Everett Harlow, Proven Alternatives
Energy at Stanford (Systems Perspective): Master Plan, Cardinal Co-gen, Energy Efficiency, Current Issues	Steve Briscomb and Scott Gould, Stanford Univ. Utilities Div.
The Greening of the White House	Kathleen Cruise, Energy Consultant
Stanford Expansion: Planning Future Projects	David Neuman, Vice Provost for Planning, Stanford University
Global Context Continued: Critique of Macroeconomic Modeling Approaches to Global Cost-Benefit Analyses	Stephen H. Schneider
Energy and Society: A Developing World Perspective	Ashok Gadgil, Lawrence Berkeley Laboratories
Sacramento Municipal Utilities District: DSM and Alternative Energy Sources	Serafina Auster, Earth Systems Program, Stanford University
Past Student Projects at Stanford	ES10x students
Current Student Projects	ES179 students