ON THE ROAD TO ENERGY SOLUTIONS

Teaching Energy and Sustainability in the Field

Field-based courses have had a tremendous influence on my education and career by providing invaluable experience in making first-hand observations and grappling with complex scientific problems. As hard as we try as college instructors to make the classroom environment more interactive, there is no substitute for the impressions formed by students when they see the complexities of natural processes unfold in front of them. Field courses also require students to focus on a single topic for weeks at a time, free from the distractions of campus life and our "wired" society, resulting in more engaged learning. And finally, interaction with practitioners in the "real world" provides a perspective that cannot readily be obtained from academicians.

Last summer my colleague Rod Ewing and I taught a field course, and the experience was so rewarding that we thought it was worth sharing with the *Elements* readership. For many years we have taught courses in geology and ecosystem science at the University of Michigan Camp Davis Rocky Mountain Field Station (UM-RMFS) in Jackson Hole, Wyoming, USA. As we drove past energy-related sites, they piqued student interest, but we never had time to visit them or discuss the science of energy production in detail. In response to student interest, we developed the course Sustainable and Fossil Energy: Options and Consequences, which is devoted entirely to the study of energy systems. The premise is that students cannot fully understand and form opinions about the pros and cons of various energy options until they have seen the fuel cycles for themselves. We base the course curriculum around visits to energy facilities in Wyoming and Idaho, discussions with individuals working at these facilities, and experiments with energy usage and renewable energy systems at our field station.

Last summer we followed fuel cycles from the mining of raw materials all the way to the production of energy. We began with fossil fuels and a tour of one of the largest coal mines in North America, where we learned about coal extraction and postmining land remediation. We witnessed the vast railway system that brings coal from Wyoming to power plants across the country, and a railcar with 100 tons of coal became our standard unit of energy for comparison with other energy sources. This was followed by a visit to a coal-fired power plant, where students learned about the combustion process, turbine design and operation, the water needs of power generation, and the technologies used to control emissions of sulfur dioxide, mercury, and other pollutants. We also traveled through several oil and gas fields and visited an operating oil refinery as well as a former refinery site where we learned about groundwater and soil remediation.

Next we explored the nuclear fuel cycle, beginning with a visit to an in situ–leaching uranium mine. Of particular interest were the vast well-fields and the chemical processing of leachate into uranium oxide or "yellowcake." A uranium mine ghost town provided the perfect setting to discuss the volatile economics of uranium. We visited the Idaho National Laboratory to learn about nuclear reactors and toured the first reactor ever to generate electricity (EBR-1) as well as an operating advanced test reactor. A highlight of this visit was peering into the water pool and observing the "blue glow" of the Cherenkov radiation caused by the spent fuel rods. The students were amazed to be standing less than 25 feet above spent nuclear fuel, and this experience had a profound effect on many of the students' views of nuclear energy.

The second half of the course explored renewable energy resources. We surveyed and installed a micro–hydroelectric generator at the field station and studied the relationships between head, flow rate, and power generation. The light powered by this generator was a beacon reminding the class of the renewability of hydroelectric power. Next we visited a major power station on the Snake River, where we learned the intricacies of syncing turbines to the grid and discussed the challenges imposed by dramatic seasonal fluctuations in river discharge. This was followed by a visit to a small run-of-the-river hydroelectric plant that was recently certified as "low-impact" because it has only minimal impact on the stream ecology. The juxtaposition of these highly contrasting hydroelectric projects made the students stop and consider the differences between high- and low-impact installations.

Participants in Geological Sciences 344—Sustainable and Fossil Energy: Options and Consequences

The town of Jackson (Wyoming) provided an ideal setting for sparking a debate among the students over what it really means to be "carbon neutral." Jackson has admirably initiated a plan to make the public works department carbon neutral by purchasing all its power from the low-impact hydroelectric plant that we visited, and the town pays a "green premium" for this energy. The town has also installed grid-connected photovoltaic systems on public buildings and at its wastewater treatment plant, and has constructed energy-efficient buildings. A visit to these facilities and discussions with town officials about the energy-sustainability project was a highlight for many students interested in sustainable systems.

The final alternate-energy visit was to the wind farms that are rapidly being built in eastern Wyoming thanks to recent tax incentives. We visited an operating wind farm and a facility being installed on the former site of an oil refinery. We had the opportunity to peer up into the vertical support of a wind turbine and were all impressed by its immense size. The students were able to form their own opinions about the noise associated with turbines and their impact on the aesthetics of western landscapes. We met with local experts and discussed the ecological and economic impacts of wind power, and the need to balance the variable output of wind generators on the grid.

As a culminating exercise, the students researched and reported on an alternate energy plan for UM-RMFS. Students monitored energy usage across the facility through a 24-hour cycle. They collected and analyzed data on energy production from an on-site solar photovoltaic array, a micro–hydroelectric turbine, and weather stations that provided wind-speed data. They also surveyed various parts of the property to assess the feasibility of hydroelectric power on two different rivers and to evaluate the potential of pumped storage. Finally, students were challenged to use all that they had seen and learned during the course to develop recommendations for an energy plan for the State of Wyoming. Judging from student reactions to this course, I am confident that it transformed many of their views on energy issues and technology. Classes such as this can be expensive, and we are grateful for support from the Graham Environmental Sustainability Institute and the Provost's Office at the University of Michigan. When financially possible I urge educators to consider using field courses to maximize student–faculty interaction, allow students to interact with experts, and enhance student understanding. Needless to say, this is not the type of experience one can gain in the classroom, nor is it what most educators think of when they discuss the trend toward distance learning!

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