

Center for Sustainable Energy
University of Massachusetts Lowell
Annual Report
August 13, 2004

1. Brief Overview of Center

In the abstract, the Center for Sustainable Energy exists to develop systems to provide energy for various end uses in an environmentally and economically sustainable manner. In the concrete, past and present projects in the center have focused on rural renewable energy systems for medical, educational, town, and agricultural use, solar/electric/fuel-cell vehicles, photovoltaic-assisted lighting, building thermal efficiency test methods, solar crop drying, solar design tools, solar resource databases, and PV battery testing. The center is unique in the degree to which it combines undergraduate and graduate education, research, public service, service-learning, and public education into its projects.

Mission Statement

The Center for Sustainable Energy seeks to improve energy efficiency in end-use sectors and to increase the diversity of energy resources consistent with an economically and environmentally sustainable future. The center strives to combine undergraduate and graduate education, research, public service, service-learning, and public education into its projects.

2. Objectives

More specific objectives within this broad mission include:

- Be a leader in village renewable energy systems through research and education.
- Incorporate service-learning with sustainable energy projects into engineering courses at U Mass Lowell.
- Design and install solar/hydro systems for vaccine refrigeration, transceiver radio communication, lighting, laptop PCs, water purification, and agriculture for remote medical clinics, schools, and towns in Peru and develop infrastructures for local people to take over development and maintenance of such systems.
- Develop solar electrolyzer-fuel cell systems for remote areas.
- Provide access over the web to our database of solar resource measurements for developing countries.

3. Focus Areas: Discovery/Learning/Engagement (Research/Teaching/Service)

Some of our joint accomplishments in the last year include:

- Trips to Peru (July 2003, January 2004, June 2004) with several graduate and undergraduate students to install systems, most of which harvest energy with photovoltaic modules, solar thermal collectors, and microhydro turbines and which provide radio transceiver communication, lights, vaccine refrigerators and other medical devices, water supply and water purification, roads, aquaculture fish, laptop computers, and science experiments in schools, medical clinics, and municipalities. The villages in general have no electricity, no telephone service, no space heating, biweekly bus transportation, and untreated drinking water, in several cases only from open streams. What makes this rural development program unique is that most of the work has been done by students in credit-bearing courses with service-learning.
- July 2003 trip highlights include:
 - We installed a solar water pump and water distribution system for Huayash (with 100 people) and a sand filtration system. Previously, the people got their water in buckets from the river about a kilometer away.
 - Put transceiver radios and antennas in the clinics in the towns of Culebras and Pariacoto.
 - We installed a complete solar radio and light system in the clinic at Pumapucllanan at an elevation of 3400 m (about 11,000 ft).
 - Completed nutrition and health surveys at 2 hospitals and 12 clinics. Also distributed donations of medicine and supplies.
 - Installed several systems with PV panels and batteries for laptop PCs in schools: Lower Huamba, Quian, Erajirca, and Pilco.
 - In Quian we made the final connection between the water purification system and the water supply system, which the local folks completed after we left in January. This system was a major undertaking of cooperation between us and the town that we are particularly proud of. The town now has water from the spring about a mile away as well as a supply of purified drinking water from a couple of common taps. Previously they got water from a river with buckets.
- January 2004 trip highlights include:
 - We finished the solar water pump and water distribution system for Huayash (with 100 people) and the sand filtration system.
 - Installed transceiver radios and antennas in the towns of Port of Huarmey and Chacchan.
 - We installed a complete solar radio and light system in the clinic at Fortaleza at an elevation of about 3000 m (10,000 ft).
 - We continued with our nutrition and health surveys at the new clinics. We also distributed donations of medicine and supplies.
 - In the clinic in Huamba, we installed another fluorescent light in one of the offices and a nebulizer. One of our crew, Lesley Hirl, a nursing student, helped a sixteen-year-old mother deliver a baby—a first for our project!
 - We performed a lot of preventive maintenance and small repairs in many clinics and schools. We installed a new vaccine refrigerator in Quian (courtesy of the Rotary of Dracut).
- June 2004 trip highlights include:

- We installed a radio system in the clinic at Casa Blanca in the Casma Hospital network. We converted the radio in Chacchan to a solar-powered system. We also traveled to Colcabamba to repair the solar radio system there. These last two clinics, even though there is electricity to the town, cannot afford to pay the electric bill and therefore rely on our solar panels.
 - In Quillapampa we installed a PV-powered water pump on a platform floating in a wide shallow well in addition to a supply tank on the hill above the town.
 - Helped start solar lantern ventures in Chacchan/Fortaleza and Quian (New England Biolabs Foundation grant) with Jesus and Eduardo in Lima.
 - Designed and installed a unique solar sterilizer in Huamba.
 - Designed, constructed, and distributed more efficient oxygen mask systems in several clinics.
 - Designed, manufactured, and fit a leg prosthesis for Javeth, a young girl, in Huarney.
- Service-learning has been incorporated into a total of nine engineering courses by John Duffy (reportedly more than any other engineering professor in the country)
 - We cooperated with the Nursing Department and had three nursing students work with us in Peru. They worked on health needs assessment, obtaining donations of medical equipment, and development of educational materials and preventive medicine programs for the villages. We also worked with the Physical Therapy Department to design and build a prosthetic leg.
 - A graduate from the National Engineering University in Lima, Peru finished the solar engineering MS program here and worked in conjunction with the center. Peter Aurora now is an intern at RWE Shott, a local PV manufacturer. He plans eventually to return to Peru to continue solar work in rural areas, which will help ensure sustainability of the efforts.
 - Two students completed master's degrees in solar engineering with their theses based on work done at the center. Two students completed MS degrees in solar engineering with projects done at the center. Two doctoral students defended their proposals.
 - One doctoral student is expected to finish his thesis in September. One doctoral and eight MS students are expected to complete their degrees with theses or projects in the center within the next year.
 - A paper was published in *Solar Energy*, and another was accepted for publication with minor revisions. Two others were submitted to the journal. Another paper was submitted for an annual book on advances in solar energy, at the request of the editor. All were on solar electrolyzer/fuel cell systems. (See list below.)
 - Two graduate courses were taught entirely over the web (22.521 Solar Engineering Fundamentals and 22.527 Solar Systems Engineering)
 - We submitted proposals or preproposals to: NSF, World Bank, New England Biolabs Foundation, Massachusetts Technology Collaborative Renewable Energy Trust, NIH, and various UML entities: Diversity, Teaching and Learning, and the Healy Service Endowment.
 - Six grants were obtained as a result of these proposals:

- Assessment of MTC Green Buildings; sponsor: Massachusetts Technology Collaborative Renewable Energy Trust (\$59,000; 2004-05)
- SLICE: Service-Learning Integrated throughout Courses in Engineering; sponsor: NSF planning grant (\$100,000; 2004-05)
- Solar Lantern Micro-Enterprise for Peruvian Villages; sponsor: New England Biolabs Foundation (\$8250; 2004)
- Diversity in Engineering through the Village Empowerment Project; sponsor: UML Council on Diversity and Pluralism (\$2000; 2004-05)
- Multi-Disciplinary Service-Learning Capstone Design Course, Teaching and Learning Seed Grant, UML (\$2000; 2004-2005).
- Interdisciplinary Service-Learning Projects, Healy service grant, UML (\$1200, 2003-2004)
- The World Bank accepted our preproposal “Optimization of village infrastructure for development: Peruvian aquaculture” and selected us as a finalist (one of 186 finalists out of more than 2,700 submissions from over 133 countries) with a travel grant to submit a proposal in person in Washington, DC in December and participate in the World Bank Developmental Marketplace Global Competition. Unfortunately, we were not among the 40 projects chosen for continued funding.
- Innovative student design/research projects for developing countries were completed at the center:
 - Photocatalytic water purification system
 - A cost-effective solar lantern and LED reading light
 - A prosthetic leg for a young girl in Peru
 - A novel solar autoclave for sterilizing medical equipment
 - An innovative oxygen delivery mask which is 80% more efficient than existing masks
 - Complete water supply systems with solar pumps for the towns of Huayash and Quillapampa
 - Design and installation of aquaculture systems: for trout in Malvas and crayfish in San Miguel in Peru
 - Efficient PI (proportional integral) controller for a portable vaccine refrigerator system
 - Model of a solar electrolyzer/fuel-cell system for remote areas

The center had the following grants and contracts since June 2003:

Village Empowerment: Peru Project; sponsors: private donations (\$6,000).

SLICE: Service-Learning Integrated throughout Courses in Engineering; sponsor: NSF planning grant (\$100,000; 2004-05)

Solar Lantern Micro-Enterprise for Peruvian Villages; sponsor: New England Biolabs Foundation (\$8250; 2004)

Diversity in Engineering through the Village Empowerment Project; sponsor: UML Council on Diversity and Pluralism (\$2000; 2004-05)

Multi-Disciplinary Service-Learning Capstone Design Course, Teaching and Learning Seed Grant, UML (\$2000; 2004-2005).

Interdisciplinary Service-Learning Projects, Healy service grant, UML (\$1200, 2003-2004).

Combining Web-Based Courses with Experiential and Service Learning, Teaching and Learning Seed Grant, UML (\$2000; 2003-2004).

Diversity in Engineering through Service-Learning; sponsor: Center for Diversity and Pluralism, UML (\$900; 2003-2004).

Facilities and Equipment

The center moved into a new lab E407 in April 2004, courtesy of the dean of engineering. It has 50% more space than the previous lab in KI107. The center has the following available for research, teaching, and public service: photovoltaic modules, pyranometers, electrical test equipment, inverters, charge controllers, an X-Y scanner for spatial response of PV cells and a variable spectrum cell tester, a considerable library on photovoltaic systems, several displays on PV systems for the general public, the 1993 Sunrayce race car and trailer, a phase change heating system for electric vehicles, heat recovery ventilators, a lab-scale fuel cell, a lab-scale electrolyzer, a solar resource database for developing countries, rural electrification systems, microhydro systems, and water pasteurization solar collectors as well as four Campbell Scientific data loggers (three in Peru and one in the lab).

The center has historically concentrated on development, installation, testing, and/or monitoring of solar systems in the field. Most experimental work is done off campus, at sites ranging from Lowell to Latin America, Somerville to Sri Lanka, and Braintree to Bangalore.

4. Faculty/Staff/Student Members

The following faculty/staff are members of the center:

John Duffy, Director (as of May 1996), Mechanical Engineering Department (solar electrolyzer/fuel cell systems, electric vehicles, thermal testing of buildings, passive solar systems, PV systems, solar rural systems)

Raul Raudales, Principal of Mesoamerican Development Institute (solar crop drying, solar water purification)

Paul Soper, former University Chaplain, Catholic Center (developing countries)

Cheryl West, research associate, formerly with the Center for Work, Family, and Community, presently doctoral candidate Work Environment program (aquaculture and service-learning)

Juan Rodriguez, Graduate School of Education (bilingual education, distance learning, sociology of Quechua people)

Sam Mil'shtein, Electrical Engineering Department (PV cells, high school education programs)
Alan Rux, Electrical Engineering Department (solar race cars, solar radios, assistive technology)
Jack Apflebaum, Industrial Technology, Professor Emeritus (solar in developing countries, biomass digesters)
Maria Brunette, Work Environment Department (Peru Project)

The following graduate students have worked in the center since June of 2003:

Salinee Tavaranan, solar lantern design and development (MS thesis, 2003)

Peter Aurora, modeling and control of a solar electrolyzer/storage/fuel cell system (MS thesis 2003)

Dismas Makori, solar coffee drum dryer (MS project 2003)

Sandeep Baidwan, model of a large transmission network for stability (MS project, 2004)

George Nitschke, solar ponds for hydrocarbon and water production (D.Eng. in process).

Steve DaSilva, energy efficient vaccine refrigerator (MS thesis in process).

Nelly Vladmirsky, CPC photovoltaic roof shingles (MS thesis in process)

Peter Dubro, solar water purification with TiO₂ catalyst (MS thesis in process)

Ujjwal Bhattacharjee, environmental impact assessment of dye-sensitized solar cells (D. Eng. in process)

Christopher Lin, engineering service-learning modules for high school students (MS thesis in process)

Kushagra Nandan, performance of ventilated photovoltaic modules (MS thesis in process)

Somchai Jiajitsawat, solar vaccine refrigerator experimental development (D. Eng. in process)

Nuchida Suwapeat, optimal design algorithm for reliability of solar remote communication systems (D.Eng. thesis in process)

Ittipon Tungarayabus, biodigester and efficient housing for rural Thailand (MS thesis in process)

Micah Krider, flexible data acquisition system for remote solar systems (MS thesis in process)

Dave Webber, photovoltaic two-meter airplane development (MS project in process)

Nto Diarra, stochastic systems approach to solar design with applications in Mali (D. Eng. in process).

Students directly supported by CFCI grant, 2003-04:

Micah Krider, Nelly Vladmirsky, and Kushagra Nandan.

Undergraduates working on projects through the center:

Jennifer Mangano and Linda Barrington, efficient, inexpensive medical oxygen mask (capstone course design project, spring semester 2004)

Lisa Gamache, Joy Sanders, and Darcy Hornberger, prosthetic leg for developing countries (capstone course design project, spring semester 2004)

Marc Evans and Richard Deschenes, solar autoclave for developing countries (capstone course design project, spring semester 2004)

Publications (since the summer of 2003)

Papers:

Trelles, J.P., and J.J. Duffy, 2003, "Numerical Simulation of Porous Latent Heat Thermal Energy Storage for Thermoelectric Cooling," *Journal of Applied Thermal Engineering*, Vol 23, No. 13, p. 1647-1664, September.

Ananthachar, V., and J.J. Duffy, 2004, "Efficiencies of Hydrogen Storage Systems Onboard Fuel Cell Vehicles," *Solar Energy*, in press.

Shapiro, D., J. J. Duffy, M. Kimble, and M. Pien, 2004, "Solar-Powered Regenerative PEM Electrolyzer/Fuel Cell System," *Solar Energy*, accepted for publication.

Bhattacharjee, U., 2004, Financing Options for Clean Development Mechanism Projects, Proceedings of the World Renewable Energy Congress VIII, Denver, August.

Presentations:

Duffy, J., 2003, "UML Peru Project," invited presentation, Dracut Rotary, September 30.

Duffy, J., 2003, "Examples of Service-Learning in Engineering," invited address to faculty, Wentworth Institute of Technology, Boston, October 22.

Duffy, J., 2003, "Optimization of Village Infrastructure for Development: Peruvian Aquaculture," invited poster presentation, Developmental Marketplace, World Bank, Washington, DC, Dec. 1-2.

Duffy, J., 2004 "Service in Science, Engineering, and Math: Developing the Equations," Discussant and session chair (invited), Demonstrating the Public Value of Higher Education: A Northeast Regional Campus Compact Conference, April 15, Worcester, MA.

Duffy, J., 2004, "Village Empowerment: Peru Project," invited presentation, joint meeting of UML Councils on Diversity and Pluralism, CITA, and Teaching and Learning, May 10.

Patent Application:

Duffy, J.J., and D. Shapiro, Electrolyzer Pressure Equalization System, Application No. 10/421,668, Publication No. US 2004/0072040 A1, April 15, 2004.

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