

Center for Sustainable Energy

University of Massachusetts Lowell

Annual Report 2007-08

July 28, 2008

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 systems; photovoltaic-assisted lighting; green building thermal efficiency test methods and case studies; solar crop drying; solar design tools; solar resource databases; and solar electric vehicles. 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. In recent years focus has been placed on service-learning promotion and research not only related to energy issues but to education and service of students and faculty of engineering and other academic disciplines.

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. The mission and major purposes of the University of Massachusetts Lowell are to provide to students an affordable education of high quality and to focus some of its scholarship and public service on assisting sustainable regional economic and social development. The Center goals help support the overall mission of the university.

2. Objectives

More specific objectives within this broad mission include:

- Be a model of village empowerment through research and education to meet needs of the world's poor through sustained collaboration with a selected network of villages with interdisciplinary projects.
- Work with faculty to incorporate service-learning projects into mainstream courses throughout the College of Engineering in particular, but other colleges and other universities also.
- Design and install solar/hydro/biogas 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.

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

Our focus areas that in general combine discovery, learning, and engagement (research, teaching, and service) include:

- The Village Empowerment Project involves the development of systems appropriate for use in developing countries: low cost; reliable; sustainable in terms of energy, environmental impact, and economics. Students, both graduate and undergraduate, develop such systems as parts of service-learning projects in courses and theses for graduate degrees. Trips have been made twice a year for two weeks since August of 1998, led and organized by the center.
- Service-Learning Integrated throughout a College of Engineering: SLICE. The goal here is integrate service-learning (S-L) projects into mainstream required courses in the engineering programs so that every student has at least one course every semester with S-L. One of the objectives, besides better learning of subject matter in the courses, is recruitment and retention of underrepresented groups in engineering. To date, over half the engineering faculty (along with a few others in other colleges) have incorporated S-L into at least one course. The center director is the faculty coordinator for this project and Principal Investigator of an NSF grant for SLICE.
- What appears to be the only academic program with graduate degrees explicitly in energy engineering (solar) is essentially run in collaboration with the center. The director of the center is the graduate coordinator of that program.
- Applied research and development: fuel cell and electrolyzer thermal modeling; electrolyzer and hydrogen and oxygen storage systems development; fuel cell vehicle hydrogen storage comparisons; complex solar system design tool for reliability; PV-thermal collector field testing; solar lantern and LED lamp development; data acquisition systems for remote PV systems; thermoelectric, solar phase-change vaccine refrigerator development; solar crop dryers; photocatalytic water purification with dye indicator for disaster relief and remote regions; life cycle environmental impact analysis of PV modules; energy efficient aquaculture; optimal design method for solar water pumping systems; solar drip irrigation; solar autoclaves; in-depth case studies of green buildings; energy implications of scoring systems for green buildings; biogas digesters for cold climates; geopressured-geothermal, solar conversion system to produce potable water; compound parabolic concentrators with thermoelectric modules; energy independence for a tribal band in New Brunswick with biomass; solar bathroom modules for a tribal band in southern Arizona; and remote sustainable development.

4. Faculty/Staff Members

The following faculty/staff are members/collaborators 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)

Hong Wei Sun, Assistant Professor, Mechanical Engineering (MEMS micro systems, solar thermal concentrators).

Diana Archibald, Associate Professor, English. (service-learning, Village Empowerment)

Linda Barrington, College of Engineering Director of Service-Learning.

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 (service-learning)

Alan Rux, Electrical Engineering Department (solar radios, assistive technology)

Bill Moeller, Professor Emeritus, Civil Engineering (sustainable development)

In addition, there are about 36 faculty members total (including the dean and three department chairs in the College of Engineering) that have incorporated service-learning into their courses as part of the SLICE initiative in the college of engineering. The initiative is led by John Duffy of the Center.

5. New Faculty and Staff Affiliations (last year)

We have collaborated with the following new faculty and staff:

- Deirdra Murphy, Assistant Professor, Physical Therapy. Advises PT students working on the Village Empowerment Project; went to Peru June 2007 and then with two students June 2008 to work with disabled local students and develop service-learning projects.
- Nicole Champagne, Associate Professor, Health Education. Service-learning projects for Health Education students. Went to Peru with two students June 2008 with the Village Empowerment project.
- Diana Archibald, Associate Professor, English. Went to Peru January 2008 with the Village Empowerment project. Her writing students have worked with VE project also.
- Chad Montrie, Associate Professor, History. A specialist in video history, Chad went to Peru January 2008 with the Village Empowerment project and took extensive videos. He is working with students to develop several videos about the project and the students involved.
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6. Students

The following graduate students have worked in/with the center since June of 2007:

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

Ujjwal Bhattacharjee, financial incentives for renewable energy (PhD. in process)

Nto Diarra, stochastic systems approach to solar water pumping design with applications in Mali (PhD. energy engineering--solar).

Manuel Heredia, solar water purification with bottles coated with TiO₂ and service-learning (PhD in process) (support: CFCI, NCIIA, NSF-SLICE).

Jorge Barrientos, green building case studies and life-cycle environmental impact of PV modules (M.S.).

Tanya Martinez, total renewable energy resource utilization analysis for northeastern New Brunswick (MS thesis 2008).

Eric Morgan, service-learning and photocatalyst coating of bottles for solar water purification (M.S. candidate).

Robert Williams, service-learning and study of byproducts safety of photocatalyst and dye indicator from solar water bottle purification (M.S. candidate).

Carolina Barreto, **Fulbright Scholar**, solar agricultural irrigation systems (M.S. candidate).

Rafael Castro, solar thermal towers (M.S. candidate).

Vivian Crespo, rural solar system for an Indian reservation in Arizona (M.S. candidate).

Chigbo Mgbemene, **Fulbright Fellow** for one year, faculty member from Mechanical Engineering Department of University of Nigeria, Nsukka; solar compound parabolic concentrators with thermoelectric modules for electricity generation.

Bharath Srinivasan, green building design (MS in process)

Sneha Sriwastava, solar-green building design (MS in process)

Littee Kitpipit, solar utilization for industry in Thailand (D.Sc. in process)

Several others supported by the SLICE grant on service-learning under the direction of other faculty.

In all, 8 graduate students were supported financially through the center.

In addition, 6 undergraduates (Ryan Burns, Ian Crabtree, Greg Pawlowski, Shawn Furey in ME and Bonnie Tacheron and Kelly Oslin in CE) worked on capstone design projects through the center.

7. Current Discovery/Learning/Engagement Projects

Major current projects include:

- Solar water purification with recycled polyethylene plastic bottles coated inside with TiO₂ photocatalyst and with a dye indicator in the water that disappears when the water is clean. The work this past year was performed by Manuel Heredia, a doctoral student in the energy engineering program, supported in part by CFCI, as well as Robert Williams and Eric Morgan, both graduate students in the energy engineering program and supported in part by the National Collegiate Inventors and Innovators Alliance. The focus was on: changing the manufacturing process of coating the recycled plastic bottles to make it safer and easier for village microenterprises; testing the long-term storage capability of the water purified in the bottles; analysis of the efficacy of the indigo carmine pill as a dye indicator of purity. The key results to date include the following:

- Organisms and chemicals destroyed by the process: All surveyed the literature extensively for evidence of the different types of harmful organisms and chemicals destroyed by the hydroxyl ions produced by the UV light and photocatalyst. Many studies have been performed with the TiO₂ powder mixed with water for detoxification of waste water subjected to UV light in laboratories, but the results should be applicable to the methodology being developed in this study. Almost all bacteria, spores, fungus as well as many pesticides and herbicides in addition to toxic forms of arsenic are eliminated by UV light and TiO₂.
 - Manufacturing improvements: Instead of dangerous perchloric acid to make the TiO₂ emulsion adhere to the inside of the bottles, through testing ten alternatives, Eric found that sodium acetate worked just as well and is much safer to use. Using the stoichiometry Eric calculated, Robert made sodium acetate in Peru from baking soda and vinegar purchased in the market and coated local recycled bottles. The bottles coat well and maintain their coating in the sun. Eric's tests in Massachusetts show this film is durable and able to withstand repeated exposure to sunlight (UV) as well as repeated refills of water.
 - Storage capabilities: Using E Coli to represent bacteria contamination in untreated water, Robert has found that E. Coli do not regrow in stored water bottles that have been coated with the safer photocatalyst emulsion and exposed to the sun until the dye disappears. Robert uses an incubated growth medium for counting the bacteria in test samples. We are storing more treated bottles and will test for E. Coli after several months.
 - Indigo carmine suitability as an indicator of purity: Manuel tested the UV and visible transmissivity of the water solutions during the dye diffusion and decay processes. The dye concentration must be high enough to be seen but low enough to allow UV light penetration through the water to the photocatalyst coating on the back wall of the bottles. Experiments so far indicate that the dye is a good indicator of the destruction of harmful organisms and chemicals since the dye is destroyed along with the other chemicals. Both the dye and TiO₂ are classified as food additives by the FDA.
 - Commercialization: Robert is in Peru until September 1, 2008 and is refining the manufacturing process of coating the bottles. He will try to start a small microenterprise in an appropriate village. Undergraduates developed a business plan for the bottles as a project in a business school course in innovations, taught by Professor Steve Tello.
- Village Empowerment: Two more trips were made to Peruvian villages, in January and June 2008, with 18 and 15 students/volunteers, respectively. For the first time, four other UML faculty members besides the director also made the trips this year. And for the first time in ten years, the director did not make a trip because of heart bypass surgery in December. We now have over 80 systems in 44 different villages in the same region. The villages in general have no electricity, no telephone service, no space heating, biweekly bus transportation, and untreated water, in several cases only from open streams. The systems, which harvest energy with photovoltaic modules, solar thermal collectors, and microhydro turbines and in some cases from the grid, 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. (<http://energy.caeds.eng.uml.edu/peru-07/index.shtm>) Some of the systems have dramatic impacts. For example, in perhaps the most remote village of the group, Huallmi, with no electricity and no telephone, in the six months prior to our installing a transceiver radio in the medical clinic in January 2006 there were seven deaths related to childbirth due to delays in getting medical help; from January 2006 to our return in June 2006 there were no deaths in childbirth. Technologies developed and installed with graduate and undergraduate students as well as volunteers during the past year include:

- Inexpensive radio transceivers for medical clinics, most solar powered. To date, 37 radio systems have been installed.
 - Solar pumping systems for water supply for whole villages.
 - Solar drip irrigation system to double yields.
 - Biodigester for methane gas production, with low cost plastic tube.
 - Physical therapy workshops for students in a special needs school, town people, and medical staff in three towns.
 - Prenatal clinic equipment, exercise programs, and health education for two hospitals.
 - Composting toilet.
 - Low cost more efficient wood stoves (courtesy of IIT student David Curtin)
 - Video and written documentation of projects, students, and the local people.
- Service-Learning Integrated throughout a College of Engineering: SLICE. The goal here is integrate service-learning (S-L) projects into mainstream required courses in the engineering programs so that every student has at least one course every semester with S-L. To date, over half the engineering faculty (along with a few others in other colleges) have tried S-L in at least one course. Over fifty courses have had S-L integrated so far. The center director is the faculty coordinator for this project. (<http://slice.uml.edu>)
 - Collaboration with the Tohono O'odham reservation in southern Arizona. About 11,500 members live on the reservation which is the size of the state of Connecticut, second to the Navajo reservation, also in Arizona. There are an estimated 10,000 families on reservations in Arizona without electricity. The center is helping UML students design adaptations to bathroom modules that the TO tribal college students are building for families without proper sanitary facilities. The adaptations are for homes without electricity and running water. Solar hot water systems, evaporative coolers, composting toilets, and photovoltaic systems were designed by four ME seniors for a spring semester capstone course and by Vivian Crespo for her MS thesis. Funding has been obtained for the project through Lyvier Conss of the Community College National Center for Community Engagement in Phoenix. Trips are planned for August and October to work with the instructors and students at the TO tribal college in building a prototype of the bathroom module.

There are many other current projects mentioned in various other sections under students, publications, grants, etc.

8. Publications

Duffy, John, Linda Barrington, Cheryl West, John McKelliget, Eugene Niemi, Sammy Shina, Hongwei Sun, Chris Niezrecki, Robert Parkin, Majid Charmchi, Peter Avitabile, 2007, "Service-Learning in Core Courses throughout a Mechanical Engineering Curriculum," *Proceedings American Society of Engineering Education Annual Conference*. (refereed)

Duffy, J., D. Kazmer, L. Barrington, J. Ting, C. Barry, Z. Zhang, D. Clark, A. Rux, 2007, "Service-Learning Integrated into Existing Core Courses throughout a College of Engineering," *Proceedings American Society of Engineering Education Annual Conference*. (refereed)

Barrington, L, and J. Duffy, 2007, "Attracting Underrepresented Groups to Engineering with Service-Learning," *Proceedings American Society of Engineering Education Annual Conference*. (refereed)

Kazmer, D., J. Duffy, L. Barrington, and B. Perna, 2007, "Introduction to Engineering through Service-Learning," *Proceedings of the ASME 2007 International Design Engineering Technical Conferences*, IDETC/DEC- 34491. (refereed)

Barrientos, J., U. Bhattacharjee, T. Martinez, and J. Duffy, 2007, "Green Buildings in Massachusetts: Comparison between Actual and Predicted Energy Performance," *Proceedings Annual Meeting American Solar Energy Society*.

Heredia, M., and J. Duffy, 2007, "Photocatalytic Destruction of Water Pollutants using a TiO₂ Film in PET Bottles," *Proceedings Annual Meeting American Solar Energy Society*.

Dubro, P., and J. Duffy, 2007, "Dye Indicator for the Effectiveness of TiO₂ Water Purification," *Proceedings Annual Meeting American Solar Energy Society*.

Bhattacharjee, U., C. Lin, R. Williams, and J. Duffy, 2008, Solar Energy Education with Service-Learning: Case Study of a Freshman Engineering Course, *Proceedings Annual Meeting American Solar Energy Society*. (refereed)

Duffy, J., 2008, Village Empowerment: International Service-Learning. Paper AC 2008-1163 *Proceedings of the American Society of Engineering Education Annual Meeting*. ASEE. (refereed)

Duffy, J., C. Barry, L. Barrington, D. Kazmer, W. Moeller, and C. West, 2008, Service-Learning Projects in 35 Core Undergraduate Engineering Courses. Paper AC 2008-1525, *Proceedings of the American Society of Engineering Education Annual Meeting*. ASEE. (refereed)

Burack, C., J. Duffy, A. Melchior, and E. Morgan, 2008, Engineering Faculty Attitudes Toward Service-Learning, Paper AC 2008-1521, *Proceedings of the American Society of Engineering Education Annual Meeting*. ASEE. (refereed)

Mgbemene, C., J. Duffy, H. Sun, and O. Onyegegbu, 2008, Electricity Generation from a Compound Parabolic Concentrator Coupled to a Thermoelectric Module, Paper ES2008-54122, *Proceedings of the ASME 2nd International Conference on Energy Sustainability*. ASME. (refereed)

- ◆ Published theses based on work at the center (degrees awarded by the university):
 - N'To Diarra, Design of Stochastic PV Water Pumping Systems (PhD 2007)
 - Jorge Barrientos, Environmental and Energy Impacts of Grid-Connected Photovoltaic Systems in Massachusetts (MS 2007)
 - Tanya Martinez, Total Renewable Energy Resource Utilization Analysis for Northeastern New Brunswick (MS 2008)

9. Conference Presentations

- ◆ Duffy, John, Linda Barrington, Cheryl West, John McKelliget, Eugene Niemi, Sammy Shina, Hongwei Sun, Chris Niezrecki, Robert Parkin, Majid Charmchi, Peter Avitabile, 2007, "Service-Learning in Core Courses Throughout a Mechanical Engineering Curriculum," *American Society of Engineering Education Annual Conference*. (L. Barrington presented)
- ◆ Duffy, J., D. Kazmer, L. Barrington, J. Ting, C. Barry, Z. Zhang, D. Clark, A. Rux, 2007, "Service-Learning Integrated into Existing Core Courses throughout a College of Engineering," *American Society of Engineering Education Annual Conference*. (L. Barrington presented)
- ◆ Barrington, L, and J. Duffy, 2007, "Attracting Underrepresented Groups to Engineering with Service-Learning," *American Society of Engineering Education Annual Conference*. (L. Barrington presented)
- ◆ Barrientos, J., U. Bhattacharjee, T. Martinez, and J. Duffy, 2007, "Green Buildings in Massachusetts: Comparison between Actual and Predicted Energy Performance," *Annual Meeting American Solar Energy Society*. (J. Barrientos presented)
- ◆ Heredia, M., and J. Duffy, 2007, "Photocatalytic Destruction of Water Pollutants using a TiO₂ Film in PET Bottles," *Annual Meeting American Solar Energy Society*. (M. Heredia presented)
- ◆ Dubro, P., and J. Duffy, 2007, "Dye Indicator for the Effectiveness of TiO₂ Water Purification," *Annual Meeting American Solar Energy Society*. (J. Duffy presented)
- ◆ Duffy, J., 2007, "Village Empowerment Project: Collaboration with Indigenous Peoples," invited presentation, Tohono O'odham Community College, Sells, AZ. (J. Duffy presented)
- ◆ Bhattacharjee, U., C. Lin, R. Williams, and J. Duffy, 2008, Solar Energy Education with Service-Learning: Case Study of a Freshman Engineering Course, *Proceedings Annual Meeting American Solar Energy Society*. (J. Duffy presented)
- ◆ Duffy, J., 2008, Village Empowerment: International Service-Learning. Paper AC 2008-1163 *Proceedings of the American Society of Engineering Education Annual Meeting*. ASEE. (K. Vedula presented)
- ◆ Duffy, J., C. Barry, L. Barrington, D. Kazmer, W. Moeller, and C. West, 2008, Service-Learning Projects in 35 Core Undergraduate Engineering Courses. Paper AC 2008-1525, *Proceedings of the American Society of Engineering Education Annual Meeting*. ASEE. (K. Vedula presented)

- ◆ Burack, C., J. Duffy, A. Melchior, and E. Morgan, 2008, Engineering Faculty Attitudes Toward Service-Learning, Paper AC 2008-1521, *Proceedings of the American Society of Engineering Education Annual Meeting*. ASEE. (K. Vedula presented)

10. Collaboration with other Centers/Institutes and/or Departments

The center collaborates with approximately 35 faculty members through the SLICE and Village Empowerment projects mainly in developing S-L projects in undergraduate and graduate courses, including faculty in the college of health, college of arts and science, and the business school. (<http://slice.uml.edu>)

11. Regional/Local Outreach (Other Institutes of Higher Education, Industries, Government Agencies, schools, etc.)

The center collaborates with at least 12 local community partners in S-L projects (<http://slice.uml.edu>). Of course, we collaborate with various government bodies (Ministry of Health, Ministry of Education, and local town governments) in 44 villages in Peru. Other collaborative endeavors with other universities are mentioned under the faculty and publication sections above.

12. Proposals submitted/Awarded 2007/2008

Proposals submitted include:

- ◆ NSF International Research and Education in Engineering Program
- ◆ EPA P3
- ◆ Encore Foundation

Grants obtained include:

- Implementation of Service-Learning Integrated throughout a College of Engineering (SLICE); J. Duffy PI, sponsor: NSF (\$1,005,000; 2005-09) no-cost extension
- NSF International Research and Education in Engineering Program, supplement to SLICE grant (\$31,480; 2007-08)
- Solar Water Purification Bottles with Dye Indicator for Developing Countries; sponsor: National Collegiate Inventors and Innovators Alliance (\$17,500; 2007-2008)
- International Service-Learning Project in the Colleges of Health and Engineering, Healy public service grant, UML (\$9600, 2007-09) with Deirdra Murphy and Nicole Champagne

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