

**Center for Sustainable Energy Annual Report**  
**University of Massachusetts Lowell**  
**July 13, 2003**

**I. 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.

**II. 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.

**III. 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.
- Work with Habitat with Humanity in building/retrofitting energy efficient houses in Lowell..
- Provide access over the web to our popular database of solar resource measurements for developing countries.

#### **IV. Discovery/Learning/Engagement (Research/Seaching/Service)**

Some of our joint accomplishments in the last year include:

- Two trips to Peru (July 2002, January 2003) with several graduate and undergraduate students to install photovoltaic arrays, solar thermal collectors, and microhydro generators to power vaccine refrigerators, lighting systems, transceiver radios, laptop PCs, nebulizers, water purification systems in now a total of 11 remote villages in medical clinics, schools, and town buildings in the Sierra. July trip highlights include:
  - Design and installation of a solar-powered drinking water purification system in Quian with filters, an ultraviolet light operating 24 hours a day, and a 10,000 liter storage tank
  - Initial installations of a radio network in a hospital in Casma and a medical post in Colcabamba (where we were told we were the first people from the US ever to visit the town) in conjunction with the local Rotary club
  - An entire vaccine refrigerator solar system in the Huamba medical post, with a new small vapor-compression fridge
  - Twelve laptop computers installed so there are now PCs in two hospitals, ten medical posts, and four schools
  - Movement and reinstallation of a PV system for battery charging and for a laptop from the old school in Cochapeti to the new school
  - A new PV system for a laptop and light in the school in San Miguel
  - Replacement of the inverter in the San Miguel hydro system so now the people have lights in the town square for three hours every night and have plans to wire the new town hall with the additional cable we brought with us
  - An agreement signed that the village of Quian will rebuild its water supply system to most houses from a spring 1.5 km away with our pipe and our project funds to purchase cement (El Nino rains of 1998 destroyed parts of their old system, so the new system will be more El Nino resistant.)
  - Headlamps with LED bulbs for several of the clinics for close work at night, along with solar battery chargers

January trip highlights include:

- Solar transceiver radio and light systems in Cochabomba and Chipre medical clinics.
- Cochapeti town hall and church solar light systems.
- Quian pressurization subsystem for UV water purification.
- Quian water supply system from a spring 1.5 km away from town; they were using buckets from an irrigation canal.

- Laptop computers in Casma hospital (4), Huarmey hospital (4), Molino posta, San Miguel school, Quian school, Malvas clinic (thanks to Partners' Health Care).
  - Community health assessments at 2 hospitals and 7 postas by UML nursing students.
  - Seminar at UNI on solar energy and fuel cells.
  - Investigated sites for aquaculture systems for Malvas (trout) and San Miguel (crayfish)
  - Two PV modules (ASE Americas) donated to a retreat house for youngsters near Lima.
  - Miscellaneous repairs: replaced inverter in San Miguel hydro, amplifier in Huamba.
  - Removed and reinstalled PV modules in Quian posta for new roof installation.
  - Inventory of all equipment installed since 1998 (about 40 systems).
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- 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 worked with Konarka Technology Inc. to help it develop dye-sensitized photovoltaic cells which are expected to be much cheaper and more flexible than existing PV cells, courtesy of a grant from the Toxic Use Reduction Institute. We worked on environmental assessment of the life cycle of the cells, a new lantern design that could be used with the new modules, and a test stand on the roof of the Engineering Building with automated data acquisition system for testing the new modules in ambient weather conditions.
  - We cooperated with Bill Mass of the RESD Department on a project funded by the Massachusetts Technology Center Renewable Energy Fund on PV installer training.
  - For the first time, we cooperated with the Nursing Department and had two nursing students work with us in Peru in January, thanks to a grant from CITA. Two more nursing students will join us in July. They work on health needs assessment, obtaining donations of medical equipment, and development of educational materials and preventive medicine programs for the villages.
  - Two graduates in mechanical engineering from the National Engineering University in Lima, Peru continued in the solar engineering MS program here and worked in conjunction with the center. One of them, Juan Pablo Trelles, completed his degree here and has an assistantship to do Ph.D. work at the University of Minnesota. Peter Aurora is an intern this summer at ASE

- Americas, a local PV manufacturer. They plan to return to Peru to continue solar work in rural areas, which will help ensure sustainability of the efforts.
- We continued on the second year of a Rotary International grant of about \$26,000 to assist in our work in Peru (mostly for hardware).
  - We continue to collaborate with the Catholic Center, which operates in conjunction with the Office of Student Life. Fr. Paul Soper (former chaplain at UML) continues in a fund-raising and advisory role with the Peru project. People of all faiths have participated in the project.
  - Four students completed master's degrees in solar engineering and one in mechanical engineering with their theses based on work done at the center. One student completed an MS in solar engineering with his project done at the center.
  - A Fulbright scholar from Germany worked this year on center projects and went to Peru with us in January and took courses in solar engineering.
  - Five papers were presented at the Annual National Solar Conference of the American Solar Energy Society in June and published in the proceedings.
  - Two graduate courses were taught entirely over the web (22.521 Solar Engineering Fundamentals and 22.527)
  - We submitted proposals or preproposals to: NSF, Shell Foundation, Oak Foundation, World Bank, Campus Compact, and various UML entities: TURI, CITA, Diversity, Teaching and Learning, and Service Endowment.
  - Innovative student design projects for developing countries were completed at the center:
    - Improved features of a very efficient solar powered vaccine refrigerator with vacuum-insulated panels that uses 2 W at steady state
    - A complete water supply and sand filter purification system for the town of Huayash, Peru (to be installed in July)
    - Design of aquaculture systems: for trout in Malvas and crayfish in San Miguel in Peru (to be started in July)

,The center strives with its projects to combine student education, research, public service, and public education. Explicit outreach activities include:

- Several members of the center are designing, assembling, and testing photovoltaic systems to power vaccine refrigerators, transceiver radios, and lights for remote villages in the Andes of Peru. Several members have traveled ten times to Peru to install almost forty systems there in addition to providing three-day workshops for

teachers with hands-on installation of PV systems for battery charging and for powering laptop computers in three schools.

- The center has provided solar race cars and educational displays of photovoltaic systems to many schools and organizations for fairs, conference exhibits, and civic events.
- The center provides training and research assistance to develop and deploy photovoltaic systems for rural electrification in many countries worldwide.

The center had the following grants and contracts since June 2002:

Peru Project; sponsor: Rotary International (\$26,000; 2002-2003)

Solar Systems in the Andes; sponsors: private donations (\$6,000; 2002-2003).

Equipment grants: 30 50W PV modules from ASE Americas; 25 50W PV modules from AstroPower; 50 used laptop computers from Partners' Community Health Care; an X-Y scanner for spatial response of PV cells and a variable spectrum cell tester from ASE Americas.

Peru Project with Engineering and Nursing Students, service grant, UML (\$1200, 2002-2003).

Service-Learning for Engineering/Health Undergraduates for Sustainable Development; sponsor: CITA small grant program, UML (\$5000; 2002-2003).

Center for Sustainable Energy; sponsor: Committee of Federated Centers and Institutes of UML (\$14,000; 2002-03).

Dye-Sensitized Nano-Scale Solar Cells: Prototype Development, Toxic Use Reduction Institute, U Mass Lowell (\$13,000; 2002-2003) and Konarka (in-kind).

## **V. Facilities and Equipment**

The center has the following available for research, teaching, and public service: photovoltaic modules, electrical test equipment, inverters, charge controllers, data acquisition systems, 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 22

foot electric bus, chargers and extra battery packs for the bus, 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, water pasteurization solar collectors, and a 700-gallon aquaculture tank and filter system.

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.

## **VI. Faculty/Staff/Student Members**

The following faculty/staff are members of the center:

John Duffy, Director (as of May 1996), Mechanical Engineering Department (solar 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, also with the Center for Work, Family, and the Community (aquaculture)

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, controllers)

Jack Apflebaum, Industrial Technology, Professor Emeritus (solar in developing countries, biomass digesters)

The following students have participated in center projects since June of 2002:

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

Luis Alegria, data acquisition system and data analysis for remote photovoltaic systems in Central America (MS thesis 2002).

George Nitschke, solar ponds (D.Eng. in process).

Nuchida Suwapeat., reliability of a solar-powered satellite communications system in the Andes (MS ME thesis 2002).

Craig Munger, data acquisition system and data analysis of thermal-photovoltaic modules (MS project 2002)

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

Adarsh Das, electrolyzer-fuel-cell energy system (MS thesis 2002)

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

Vinay Kumar A., solar fuel cell system in vehicles (MS thesis 2002)

Juan Pablo Trelles, modeling of phase change thermal energy storage with thermoelectric modules (MS thesis 2003)

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

Nelly Vladmirsky, solar radio packet data transfer

Peter Dubro, solar radio system design for remote villages, center web development

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

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

Elena Franzen, Fulbright Fellow, solar vaccine refrigerator control

Walter Lee, radio packet modem development

Christopher Lin, zero-energy house design

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

Award:

SELCO India (founded by Harish Hande, who received his doctorate two and a half years ago in energy engineering based on work done with the Center) has now installed 10000 photovoltaic systems. His company won one of two citizenship awards last year from the US Dept. of State.

## **VII. Resources**

The center has a laboratory in KI 109, courtesy of the Mechanical Engineering Department. It houses PV modules, vaccine refrigerators, 2-m band radios, and other equipment for the Peru project as well as two pieces of PV testing equipment: an X-Y scanner for spatial response of PV cells and a variable spectrum cell tester. The center has considerable equipment in remote villages in Peru. Most of it has been donated to the medical clinics, schools, and town governments in the villages. However, we still maintain the equipment, and learn from the performance of the systems, most of which were designed by students. Three PV vaccine refrigerator systems, one including a weather station, are constantly monitored, and data is stored every hour. We download the data each time we visit the sites.

The center has available numerous personal computers connected to the internet. The university has site licenses for a wide variety of general purpose programs. In addition, the center has special purpose software for the design of solar systems, such as TRNSYS, DOE II, SIZEPV, and WINDOW.

## **VIII. Publications (since the summer of 2002)**

### **Papers:**

Oakes, W., J. Duffy, T. Jacobius, P. Linos, S. Lord, W. W. Schultz, and A. Smith, 2002, "Service-Learning in Engineering," *Proceedings of the Frontiers in Education Conference*, American Society of Engineering Education.

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.

Ananthachar, V., and J.J. Duffy, 2003, "Efficiencies of Hydrogen Storage Systems Onboard Fuel Cell Vehicles," *Proceedings Annual National Solar Conference*, American Solar Energy Society.

Das, A., J.J. Duffy, and M. Kimble, 2003, "Heat Transfer Improvement for a 4 kW Regenerative PEM Electrolyzer/Fuel Cell System," *Proceedings Annual National Solar Conference*, American Solar Energy Society.

Suwapaet, N., and J.J. Duffy, 2003, "Design Tool for Reliable Solar Systems," *Proceedings Annual National Solar Conference*, American Solar Energy Society.

Hart, J., M. MacDonald, S. Montminy, and J.J. Duffy, 2003, "Drinking Water Purification System for Remote Villages Utilizing Ultraviolet Radiation and Photovoltaics," *Proceedings Annual National Solar Conference*, American Solar Energy Society.

Munger, C., and J.J. Duffy, 2003, "Monitored Efficiency of a Combined Photovoltaic and Thermal Solar Collector," *Proceedings Annual National Solar Conference*, American Solar Energy Society.

### **Presentations:**

Duffy, J.J., 2002, "Peru Project and the Rotary," (invited) Chelmsford Rotary, September.

Oakes, W., and J.J. Duffy, 2002, "Service-Learning in Engineering," Workshop (invited), Campus Compact, Nov. 5, MIT.

Oakes, W., J. Duffy, T. Jacobius, P. Linos, S. Lord, W. W. Schultz, and A. Smith, 2002, "Service-Learning in Engineering," Frontiers in Education Conference, American Society of Engineering Education, Nov.

Duffy, D., and J.J. Duffy, 2002, "Service, Stories, and Scholarship: Course Portfolios," invited workshop, Campus Compact National Summit on Civic Engagement, Nov., Providence, RI.

Duffy, J.J., 2003, "Peru Project: An Update," (invited) Chelmsford Rotary, February.

Duffy, J.J., 2003, "Peru Project: An Update," (invited) Lowell Rotary, March.

Duffy, D., and J.J. Duffy, 2003, "Civic Engagement, Stories, and Scholarship," invited workshop, Mesa Community College, AZ, March.

Duffy, J.J., 2003, "Engineering Examples of Service-Learning," invited panel presentation, Practice-Oriented Education, International Conference, Northeastern U., April.

Ananthachar, V., and J.J. Duffy, 2003, "Efficiencies of Hydrogen Storage Systems Onboard Fuel Cell Vehicles," Annual National Solar Conference, American Solar Energy Society, June, Austin, TX.

Das, A., J.J. Duffy, and M. Kimble, 2003, "Heat Transfer Improvement for a 4 kW Regenerative PEM Electrolyzer/Fuel Cell System," Annual National Solar Conference, American Solar Energy Society, June, Austin, TX.

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Munger, C., and J.J. Duffy, 2003, "Monitored Efficiency of a Combined Photovoltaic and Thermal Solar Collector," Annual National Solar Conference, American Solar Energy Society, June, Austin, TX.

Theses based on work done at the Center:  
(See students and titles listed above.)

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