

Center for Sustainable Energy
University of Massachusetts Lowell
Annual Report
July 15, 2002

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 solar electrification, 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 solar rural electrification and solar crop drying through research and education.
- Incorporate service-learning with sustainable energy projects into engineering courses at U Mass Lowell.
- Design and install solar systems for vaccine refrigeration, transceiver radio communication, and lighting in remote medical clinics in Peru and develop infrastructures for local people to take over development and maintenance of such systems.
- Develop solar electrolyzer and fuel cell systems for remote areas.
- Work with Habitat with Humanity in building/retrofitting energy efficient houses in Lowell.
- Administer the use of New England's first battery-powered electric bus.

- Provide access over the web to our popular database of solar resource measurements for developing countries.

IV. Discovery/Learning/Engagement

Some of our joint accomplishments in the last year include:

- Two trips to Peru (January 2002; July 2001) with several graduate and undergraduate students to install photovoltaic arrays, vaccine refrigerators, lighting systems, and transceiver radios in now a total of 8 remote village medical clinics in the Sierra so that medical personnel in remote villages can communicate with hospital on the coast. We installed solar-powered laptop computers in three schools in the mountains. We plan to install more schools on the trip this July. We assembled the lesson plans, student handouts, and hardware for ten lessons/experiments on renewable energy for three schools in the mountains: Malvas, Cochapeti, and Raypa. We obtained funding from Rotary International in December (\$26,000 over two years), private donations, local parishes, the Chancellor, and the local Peruvian association. Two undergraduate engineering students from Dartmouth and Cornell donated two months of their labor last summer to the project. We have submitted proposals to get additional funding from the Turner Foundation. Papers on the project have appeared in *Solar Today*, a chapter in the AAHE monograph: *Projects That Matter: Service-Learning in Engineering*, and *The 1999 National Solar Conference Proceedings*.
- Service-learning was introduced into another course (22.213 Dynamics, a required sophomore mechanical engineering course) in addition to the improvement and expansion of service-learning into seven other courses. Students analyzed the forces and speeds of children on four different rides at their local playgrounds (slides, helical slides, swings, and merry-go-rounds). They suggested safety improvements to the local community group responsible for their playground. Development and research in this area are described in papers in the above book and in the *2000 American Society of Engineering Education National Conference Proceedings*. We had a small Teaching and Learning Seed Grant from UML to develop a new course involving international interdisciplinary service-learning. Several undergraduates, majoring in history, computer science, meteorology, and criminal justice, went to Peru in January, 2001, collaborating with engineering students.
- With the Cambodian Mutual Assistance Association and the COPC, we obtained a small grant, which continued this year, from the Massachusetts Department of Food and Agriculture to continue developing Tilapia

aquaculture systems. The Center took over the complete prototype aquaculture system in February after the CMAA decided to discontinue cooperation with the project. This grant helped provide funding for an engineering graduate research assistant to improve cost/effectiveness and sustainability, administration from the COPC, day-to-day maintenance of the fish, and community and university education on aquaculture. This work helped the Center for Work, Family, and the Community obtain a large NSF grant to use aquaculture in local middle schools.

- From funding provided by TURI and CEAM, we worked with ElectroChem to develop a unique electrolyzer/fuel cell/storage system for backup power and with photovoltaic modules for electrical power in remote areas. One student obtained an MS degree in solar engineering who was supported by the TURI grant.
- We obtained a small Lindbergh Foundation grant to develop an innovative vaccine refrigerator for use in remote areas of Peru and elsewhere to help serve the 2 billion people in the world with no grid electricity and to purchase a data acquisition system and satellite ground station to deliver performance data on the vaccine system in the field in Peru. No labor is included in the grant.
- Two graduates in mechanical engineering from the National Engineering University in Lima, Peru started the solar engineering MS program here in September and will work in conjunction with the center. They plan to return to Peru to continue solar work in rural areas, which will help ensure sustainability of the efforts.
- We have received 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 project. He is scheduled to go with us next week to Peru. People of all faiths have participated in the project.
- John Duffy was invited to give a four-hour workshop on service-learning with Dr. Donna Duffy, his wife, at the Massachusetts Campus Compact Conference at U Mass Amherst this spring. Thirty faculty and staff from other universities participated.
- Three 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.
- Two papers were presented at the Annual National Solar Conference of the American Solar Energy Society in June and published in the proceedings.

- Seven innovative student design projects were completed at the center:
 - A very efficient solar power vaccine refrigerator with vacuum-insulated panels that uses 2 W at steady state
 - A micro hydro system for lights in a town in Peru that the seniors installed and tested
 - A solar coffee dryer system with improved filling and emptying, with unglazed transpired collectors
 - A human-powered nebulizer for asthma patients in rural areas
 - A complete solar water UV purification system for a whole town (Quian) in Peru, to be installed next week by the seniors
 - A very efficient vaccine fridge and backpack portable cooler for very remote areas in developing countries (to be brought down to Peru tomorrow).

The center has collaborated with other centers and departments this year and in past years. In particular, Toxic Use Reduction Institute, Center for Productivity Enhancement, and the Institute for Plastics Innovation have provided cash and/or space for the design, manufacture, and deployment of solar race cars, which provide incredible engineering education experiences for students and result in graphic messages to the public about the potential of true zero emission transport. The Community Outreach Partnership Collaborative provided support for introducing service-learning into engineering courses with community service projects with Habitat for Humanity. The Center for Industrial Competitiveness has provided seed money for the electric bus project development. The center has cooperated with the Center for Advanced Electronics in helping high school students design and build a solar race car, which was entered in a nationwide race in Indianapolis for high school students. We have collaborated on the Peru Project with the Catholic Center, the Office for Community Service, and the Program for English as a Second Language in the Graduate School of Education. We have worked with MASSPIRG and AmeriCorps volunteers on monitoring of a river in Lowell for water quality and in analyzing the safety of local playgrounds with dynamic analysis and with the Center for Work, Family, and the Community and the Cambodian Mutual Assistance Association in developing an efficient fish aquaculture system.

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 eight times to Peru to install thirty 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, the electric bus, 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 2001:

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

Center for Sustainable Energy; sponsor: Committee of Federated Centers and Institutes of UML (\$14,000; 2001-02).

Vaccine Refrigerators for Peru; sponsor: Lindbergh Foundation (\$10,500; 2001-2002).

Satellite-based network for schools in the Andes, service grant, UML (\$1600, 2001-2002)

Fuel Cell System for Remote Locations; sponsors: Toxic Use Reduction Institute (\$17,500; 2001-02) and Electrochem (in-kind support).

Solar Systems in the Andes; sponsors: UML Chancellor, private donations (\$10,000; 2001-2002).

Shared Harvest Aquaculture Innovations (with Cheryl West, COPC); sponsor: Massachusetts Department of Food and Agriculture (\$24,000; 2000-01; carried over another year)

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, 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)

Bob Parkin, Mechanical Engineering Department (hybrid electric vehicles, robotics)

Jim Sheff, Chemical and Nuclear Engineering Department (wind and geothermal energy)

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 2001:

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

Steve Fernandez, a study of locally manufactured lead-acid batteries used in stand alone home photovoltaic (SAHPV) systems in the Dominican Republic (MS thesis 2001 and paper).

Herb Sinnock, risk analysis in renewable energy investment with market and weather uncertainties (D.Eng. in process).

Meredith Lewko, bioprocessing/recycling of fish waste in aquaculture (MS ME 2002).

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

Daniel Shapiro, solar electrolyzer hydrogen-oxygen pressurization and storage system (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 in process)

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

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

Numpol Sathonpattanakij, solar thermal systems for closed-cycle aquaculture systems in cold climates (MS project 2002)

Dismas Makori, solar coffee drum dryer (MS project in process)

Vinay Kumar A., solar fuel cell system in vehicles (MS project 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 the 700-gallon tank, hydroponic trays, air pump, and filter for aquaculture as well as 35 adult Tilapia fish. It also contains a few PV modules, vaccine refrigerators, 2-m band radios, and other equipment for the Peru project. 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. Two 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 2001)

Papers:

Alegria, Luis, and J.J. Duffy, 2002, "Monitoring System Design and Results from a Typical PV System in the Dominican Republic," Proceedings of the 2002 National Solar Energy Conference, Annual Meeting, American Solar Energy Society.

Shapiro, D., J. J. Duffy, M. Kimble, and M. Pien, 2002, "Solar-Powered Regenerative PEM Electrolyzer/Fuel Cell System," Proceedings of the 2002 National Solar Energy Conference, Annual Meeting, American Solar Energy Society.

Presentations:

Duffy, J., A. Krish, and K. Tupper, 2001, Two-day workshop in Raypa, Peru, on photovoltaic principles, charging stations, and experiments for students, for teachers, sponsored by UML, July.

Duffy, J.J., 2001, "The Impact of Technology on Villages in Peru," invited seminar for honors students, UML, October.

Duffy, D., and J.J. Duffy, 2002, "Introduction to Service-Learning: What, Why, and How," (invited) Massachusetts Campus Compact Conference, April 4, U Mass

Amherst.

Shapiro, D., J. J. Duffy, M. Kimble, and M. Pien, 2002, "Solar-Powered Regenerative PEM Electrolyzer/Fuel Cell System," Proceedings of the 2002 National Solar Energy Conference, Annual Meeting, American Solar Energy Society.

Theses based on work done at the Center:

Stephen Fernandez, 2001, MS Solar Engineering

Luis Alegria, 2002, MS Solar Engineering

Daniel Shapiro, 2002, MS Solar Engineering

Nuchida Suwapaet, 2002, MS Mechanical Engineering

MS Projects:

Nto Diarra, 2002, MS Solar Engineering

Numpol , 2002, MS Solar Engineering

Meredith Lewko, MS Mechanical Engineering

Center contact:

John Duffy, Professor
Mechanical Engineering Department
University of Massachusetts Lowell
One University Ave.
Lowell, MA 01854
978-934-2968
FAX: 978-934-3048
e-mail: John_Duffy@uml.edu.

(Draft report written July 15, 2002 by John Duffy)