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SCHATZ ENERGY RESEARCH CENTER'S EDUCATION AND OUTREACH EFFORTS

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1. Introduction

The Schatz Energy Research Center (SERC) has provided education and community outreach since its inception in 1989. SERC employees attend career fairs, speak as guest lecturers in classrooms, present teacher training workshops, guide tours of the laboratory facilities and the Schatz Solar Hydrogen Project, and develop interpretive signs and brochures. Audiences include K-12, undergraduate, and graduate students; service groups such as Rotary, Chambers of Commerce, and AmeriCorps; public school teachers; and the general public. Education and outreach are important activities for SERC and are in keeping with our mission to promote the use of clean and renewable energy in our society.

2. Program Description

The objectives of the Center's education and outreach program are to increase awareness and understanding of energy issues and to give people first-hand experience with clean energy technologies. In particular, we work to help people become knowledgeable about energy resources and electricity generation, renewable energy and fuel cell technologies, as well as hydrogen as a storage medium for renewable energy. We teach what electricity is and how it is generated and help students understand how they use electricity in their daily lives. We also teach about energy resources in general and the differences between renewable and nonrenewable resources. The intermittent nature of renewable energy resources opens the door to lessons about energy storage, hydrogen, and fuel cells. Students of all ages are eager to learn about hydrogen as a large-scale storage medium for renewable energy and the fuel cells that convert the stored energy back into electricity.

The Center's education efforts take many forms, including informative tours, guest lectures, and teacher training workshops. SERC's laboratory facilities at Humboldt State University (HSU) and the Schatz Solar Hydrogen Project (SSHP) at HSU's Telonicher Marine Laboratory in Trinidad, California, are exciting field trip destinations. Over 400 students, including fourth through eighth graders, engineering classes from HSU, and day camp groups of five- to twelve-year-olds, visited the Schatz laboratory in the year 2002. In the laboratory, students see for themselves the machinery and equipment used to make and test fuel cells, and they meet the people who work in this exciting field. They see fuel cells on test benches and trace the flow of gas through pipes and the flow of electricity through wires, while observing real-time measurements on computer screens. At the

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SSHP, students experience the solar hydrogen cycle in action and learn about the technologies that are working together to provide renewable energy twenty-four hours a day. The children shown in Figure 1 are learning about photovoltaics and solar electricity during a tour of the SSHP.

Figure 1. Students learn about photovoltaics and solar electricity while touring the Schatz Solar Hydrogen Project.

In addition to guiding tours, SERC engineers travel to individual classrooms, speak to community groups, and participate in educational events. We taught over 300 students in their classrooms in 2002, including kindergarten through eighth grade single- and mixed-level classes, high school English classes, and undergraduate Chemistry classes. Additionally, we speak as guest lecturers at college seminars and business and service group meetings and for the general public at gatherings such as HSU's Renewable Energy and Sustainable Living Fair, an Earth Day event. Career fairs at the local high schools and special events, such as the Redwood Environmental Education Fair (REEF) and Expanding Your Horizons in Science and Mathematics™ (EYH), are also important educational outreach activities for SERC. REEF is a two-day event sponsored annually by the Humboldt County Office of Education and College of the Redwoods (our local community college) at which elementary and middle school classes attend interactive workshops presented by community professionals. The 45-minute workshops incorporate hands-on activities that focus on environmental concepts and issues and teach the students about their impacts on the environment. More than 100 EYH conferences are held every other year on college campuses in the United States to nurture and encourage girls' interest in science and mathematics through hands-on learning experiences and discussions with women scientists, mathematicians, and engineers.

The most important aspect of SERC's outreach program is teacher training because we can affect a greater number of students through their instructors than through direct efforts. We facilitate training workshops to increase the teachers' capacity to teach energy and electricity concepts in their own classrooms. Our experience has shown that teachers, especially in the primary grades, are interested in energy topics but are reluctant to teach about energy because they lack confidence in their own ability to understand the material. In October 2001, we presented the EPA-sponsored *Power of Teaching* workshop, a fun and interactive exploration of energy topics ranging from electricity basics to the electrochemistry and operation of fuel cells. We will teach a similar class for in-service K-8 teachers as part of the Redwood Sciences Project in August 2003.

3. Teaching Techniques

SERC's teaching techniques include interactive lectures, educational games, hands-on activities, and physical demonstrations tailored to fit the age and focus of the audience. Numerous studies have documented the underrepresentation of women and minorities in scientific fields [1, 2], while others have shown that traditional teaching methods contribute to high attrition rates among all undergraduate students in science, engineering, and mathematics programs [3, 4]. In Rosser's [5] analysis of various science education reform studies, "hands-on and interactive approaches [that] involve students directly with experimental science" emerged as a common theme. These teaching techniques are more engaging for all students, especially women and minorities, and are key elements of SERC's teaching practice.

A. Interactive Lectures

The interactive lecture portion of the Center's educational program takes the form of an open discussion, with or without multimedia. For younger audiences (grades K-6), we use an EarthBall® to maintain control over the group while still having an interactive discussion. The EarthBall® is an inflatable globe that depicts the Earth as it actually appears from space because it is based on satellite images. Only the student who is holding the EarthBall® is allowed to speak. We often use this method to discuss particular energy resources and the advantages and disadvantages associated with each. The students supply the information, and the presenters simply record their answers and facilitate the discussion.

Multimedia presentations are more engaging for older audiences (grades 7-12, college students, and the general public). The prepared slides keep the presentation organized, and the students interject questions as they arise. The visuals also aid the presenter in discussing more complex concepts. SERC has prepared multimedia presentations for a variety of audiences, including grade school and college students, teachers, business and service groups, and industry professionals, on topics ranging from basic energy concepts to details about proton exchange membrane fuel cells and their operation. The presentations are tailored to meet the individual needs, interests, and background of the audience.

B. Educational Games

SERC developed an educational game called Watts Up?™ to teach students the relationship between power and energy and to raise awareness of how they use electricity in their daily lives. As an introduction, we define power and energy and discuss electrical loads in general and specific types (electronic, heating, and mechanical), including examples of relative power levels. For instance, electronic loads, such as computers, cordless telephones, and television sets, tend to be smaller than 500 watts. Heating loads, such as toasters, hair dryers, and space heaters, are generally much larger, 1000 watts or greater. The power levels of mechanical loads, such as blenders and electric drills, vary widely depending on the size of the motor.

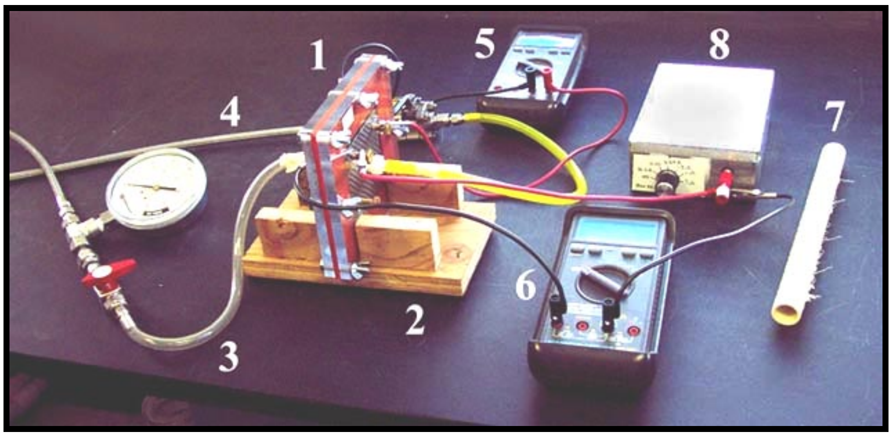
After the introduction the students arrange themselves in teams of two to four, and the game begins. We present the students with a common household appliance and ask them to guess how many watts the appliance requires to operate. After all the teams' guesses have been recorded, student helpers measure the power level of the appliance with a wattmeter, and the facilitator assigns points to each team based on the accuracy of their guesses. We include six to ten appliances in the game, such as blenders, toasters, and television sets. Although the competitive element of Watts Up?™ keeps the students interested, we try not to let the competition overshadow the real lesson. In the concluding discussion, we emphasize to students that energy consumption is a function of both the power level of the appliance and the amount of time the appliance is used.

C. Hands-on Activities

Some of the most exciting elements of the Center's education and outreach program are the hands-on activities. These activities include building electric circuits and single-cell fuel cells. The electric circuits use small batteries or photovoltaic modules as power sources and flashlight bulbs, light-emitting diodes, small motors, or radios as loads. Students learn about series and parallel circuits and the importance of matching the size of the load and the power source. They enjoy connecting the wires and experience a sense of accomplishment when the load begins to operate. The five- to twelve-year-olds shown in Figure 2 are building circuits with SERC engineer Christine Parra.

Figure 2. Day campers build solar circuits to power radios and motors.

In addition to standard electric circuit laboratories, SERC has developed a hands-on fuel cell activity. We designed a single-cell fuel cell with simple components for students to assemble, shown in Figure 3. Younger students learn about the individual components and basic operation of a fuel cell. More advanced students take the additional step of connecting hydrogen and air supplies and measuring the electrical characteristics of their fuel cells. As shown in Figure 4, this activity is a standard laboratory exercise in the Renewable Energy Power Systems class in the Environmental Resources Engineering department at HSU. These students then advance to measuring electrical performance for a full-scale fuel cell stack on a test station in SERC's laboratory.



1. Hydrogen (Anode) Side
2. Air (Cathode) Side
3. Hydrogen Supply
4. Air Supply
5. Voltage Meter (across fuel cell)
6. Current Meter (in load circuit)
7. Low-Ohm Resistive Load
8. High-Ohm Resistive Load

Figure 3. Components of SERC's single-cell fuel cell activity.

Figure 4. HSU engineering students assemble and test single-cell fuel cells.

D. Technology Demonstrations

The final component of SERC's educational program is technology demonstrations, which include a small-scale electrolyzer, a solar oven, and a portable fuel cell system. The electrolyzer that we demonstrate is actually a reversible fuel cell [6]. A 6-VDC power supply is connected to the exposed ends of graphite electrodes that are in contact with a potassium hydroxide solution. Small test tubes are filled with the electrolyte solution and inverted over the submerged ends of the electrodes to collect the hydrogen and oxygen gases that evolve at each electrode, as shown in Figure 5. Replacing the battery with a voltmeter reverses the reaction, and the device becomes a fuel cell. The meter displays the voltage of the cell as the hydrogen and oxygen gases recombine.

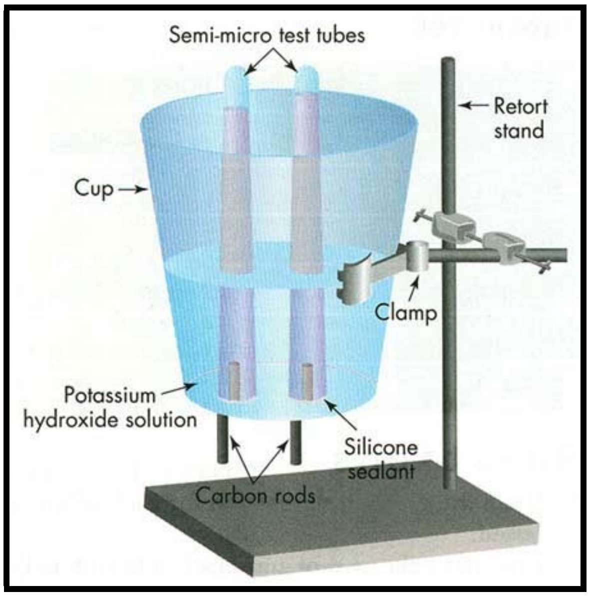


Figure 5. Small-scale electrolyzer/fuel cell apparatus [6].

In addition to electrolysis, we also demonstrate solar cooking with a SunOven®. The ability to use solar energy as the heat source for cooking can easily be demonstrated with a cup of water and a thermometer, or the lesson can be expanded to cover the light-absorbing properties of various colors by including both light and dark cups of water in the oven. Students are more enthusiastic about solar thermal energy when they are cooking edible treats, and cookies have proven to be an effective tool for demonstrating the basics of solar cooking, as shown in Figure 6. Many lesson plans are available on the Internet for building solar cookers [7, 8] and investigating the insulating and light-absorbing properties of various materials [9, 10].

SERC also has the unique ability to demonstrate fuel cell operation with our portable fuel cell power supply, Stack-in-a-Box®, shown in Figure 7. We designed it with simplicity in mind to educate people of all ages and backgrounds about renewable energy, hydrogen, and fuel cells. After discussing the basic requirements for a fuel cell, students are able to identify the individual

Figure 6. K-6th grade students bake cookies in a solar oven.

Figure 7. SERC's portable fuel cell power supply, Stack-in-a-Box®.

components on their own, and they are eager to turn the valves and operate the fuel cell. More advanced students can perform experiments that explore concepts such as system efficiency, as shown in Figure 8. At public demonstrations, people of all ages crowd around to see the system and learn about fuel cells. The first Stack-in-a-Box® was built for the Merit Academy, a private school in Santa Cruz, California, and the students used an ice cream maker to demonstrate the system at schools and conferences, including the 10th Annual National Hydrogen Association Meeting in April 1999 [11]. The ice cream maker is very popular, but any load that requires 75 watts or less can be used. The Stack-in-a-Box® also powers the laptop computer for our multimedia presentations and has become the centerpiece of our educational outreach efforts, providing students with first-hand experience with fuel cell technology and making the learning process fun and interactive.

Figure 8. Eighth grade students calculate Stack-in-a-Box® system efficiency.

4. Interpretation

Interpretive signs and brochures that educate the public about renewable energy in general and specific installations are another important aspect of the Center's education and outreach efforts. We developed interpretive signs for SunLine Transit Agency's Clean Fuels Mall as part of the Palm Desert Renewable Hydrogen Transportation Project and brochures for the Humboldt County Energy Task Force's public education campaign. The Schatz Hydrogen Generation Center, part of the Clean Fuels Mall at SunLine Transit Agency, is shown in Figure 9, and the sign that explains electrolysis is shown in Figure 10. We recently designed and installed new signs at the Schatz Solar Hydrogen Project to explain the renewable hydrogen cycle and the technologies involved. We also updated the tri-fold brochure that provides more details about the system and is available to visitors in an outdoor dispenser. We are currently working with Redwood National and State Parks to develop a sign and brochure to explain the new solar water heating system at Redwood Information Center that SERC interns designed and installed in summer 2002.

Figure 9. Interpretive signs at the Schatz Hydrogen Generation Center at SunLine Transit Agency in Thousand Palms, CA.

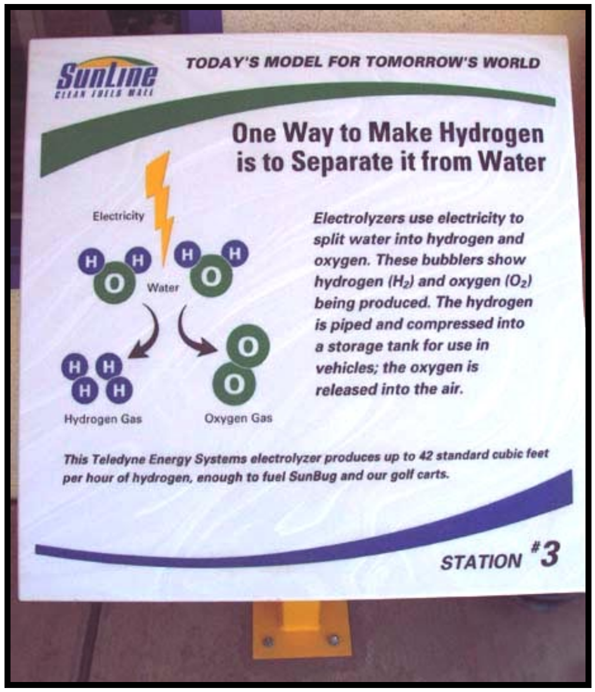


Figure 10. Interpretive sign explaining electrolysis installed in front of the Schatz Hydrogen Generation Center at SunLine Transit Agency.

5. Conclusions

The Schatz Energy Research Center's education and outreach program seeks to increase awareness and understanding of energy issues and to give people first-hand experience with clean energy technologies. We teach about energy resources and technologies and hydrogen through interpretive signs and brochures and through direct contact with students and teachers. Teaching techniques include interactive lectures, educational games, hands-on activities, and physical demonstrations tailored to fit the age and focus of the audience. Education is an important aspect of our mission to promote the use of clean and renewable energy in our society.

6. References

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7. Curriculum Vitae

Angelique Sorensen earned a B.S. in Environmental Resources Engineering from Humboldt State University in May 2000. She joined the Schatz Energy Research Center as an intern for the University-National Park Energy Partnership Program in May 2000, and was promoted to research engineer the following September. Ms. Sorensen has taught energy science to students of all ages in classrooms and at various events, including the Arcata Renewable Energy Fair and Redwood Environmental Education Fair. She also participates in teacher training workshops and educational outreach programs, such as high school career fairs and job-shadowing days and Expanding Your Horizons™, a math and science conference for sixth through eighth grade girls.

Peter Lehman is the director of the Schatz Energy Research Center and professor of Environmental Resources Engineering at Humboldt State University. He received a BS in chemistry from Massachusetts Institute of Technology and a Ph.D. in physical chemistry from the University of Chicago. He served as a postdoctoral fellow at the University of California, Berkeley, where he conducted research on the aerochemistry of photochemical air pollution. His research interests include renewable energy systems, especially solar thermal and photovoltaic technologies, and he is involved in development of solar hydrogen generation systems and in the research and production of proton exchange membrane fuel cells through the Schatz Energy Research Center.