A Hands-On Approach to Solar Energy Education

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ABSTRACT

Solar Schoolhouse is a K-12 energy educational program under development by The Rahus Institute, a 501c3 non-profit organization. The Solar Schoolhouse Program uses the Sun as a starting point for teaching about energy resources, conservation, and other energy topics. A series of hands-on energy exercises provide a lasting impression with students and lead to a greater interest in math & science subjects. The program offers resource kits which include: solar (photovoltaic) panels, electric metering lab kit (volt/amp meters, fans, pumps, lights, motors), hand crank, fuel cell, kWh plug meter, books, videos, and CDs.

In addition, the program has established a procedure for schools to purchase and install a small 1 kW Photovoltaic (PV) system. Pre-engineered kits are available, at preferred pricing. The grid-tied solar electric systems produce power which goes directly into the school and reduces the amount of electricity bought from the local utility. A data collection system records power production data, and can be used for classroom analysis exercises. As more schools install these PV systems, students can compare the performance of their system to others around the nation via the website.

Our experiences thus far, indicate that the hands-on component of our program has the greatest impact. Making electricity from sunlight, cooking food with the sun, designing and building kinetic art sculptures that move solely from the power of the sun…these are experiences that awaken a latent desire to learn more about energy issues. Our initial assumption was that each school had to have a grid-tied photovoltaic system, but now think that it's more important to provide the basic hands-on experience and allow for the development of special projects. A grid-tied PV system can be one of the special projects, as it provides a real world example of how solar energy can power our homes and schools. Lastly, our goal is to introduce a set of curriculum exercises that teachers adopt as their own and repeat every year. That will be the true measure of success.

Fig 1. Hal (aka Solarman) conducts a solar lab with Berkeley Middle School students.

1. TEACHING CONCEPT AND STRATEGY

Solar electricity is used to get student attention and generate excitement and interest about energy. We've found that teachers are eager to learn more about clean energy options, as well. This is key to integrating solar energy, energy conservation, and other energy subjects into their curriculum in a lasting fashion. The teachers must be motivated to integrate the materials. Our approach is to provide materials/curriculum through teacher workshops, such that it is the teachers that develop the skills needed to teach about energy in their classrooms year after year.

After a recent workshop for San Francisco middle school teachers, when asked what we could have done differently, the overwhelming response was "more, give us more!" Our hands-on approach helps them experience what is energy, where it comes from, and what it can do. Then we can talk about larger issues – the situation in California, worldwide perspectives and potential solutions via energy conservation, solar and renewable energy. There is a sense of hope that also emerges.

After viewing a graph of worldwide oil production, with production peaking within a few years and tapering off thereafter, a high school classroom is left in a rather somber mood. Their daily lives depend on oil – certainly the end is near. That's when we have fun and inject some hope into this dismal picture. Through smarter use of energy (becoming more efficient), adopting solar strategies to heat, cool, and electrify homes & schools, and through adoption of clean fuels for transportation… 'making the world a better place' seems achievable. Armed with the knowledge of technologies and practices that will help solve our energy situation, yet with a sense of urgency, students begin to be a part of the solution.

1.1 <u>Standards Correlation</u>

Lesson plans are correlated to California subject teaching standards. For energy, math & science are a natural fit. Social science standards can also be met through our energy curriculum. Several members of our staff are experienced teachers who fully appreciate that our lessons must help teachers achieve their teaching objective – not create 'one more thing' for them to do. All of our lesson plans are mapped to grade level requirements. In order to succeed, we must also be flexible and provide teachers with portions they can handle vs. overloading them.

Fig. 2 Kindergartner Pauline, age 6, helps teach about solar energy to a 5th grade class.

1.2 <u>Curriculum K-12</u>

Why target the full range of class levels? While certain grade levels are a better fit in matching energy curriculum to state math & science standards, students at every grade level can benefit from learning about renewable energy and energy conservation. We have taught solar to students as young as 6 years old (Fig. 2) to high school seniors and adults in the community. This generation is our future. They must become familiar with clean energy resources and energy conservation practices. Thus we seek every opportunity to provide learning experiences all the way from kindergarten through high school.

1.3 <u>Teacher Workshops</u>

Teacher workshops (Fig. 3) are a central part of our program. Through the workshops, teachers gain proficiency in the subject matter, become comfortable working with the solar equipment, and gain practice conducting energy labs. The workshops enable teachers to experience the curriculum and technology both from a student and a teacher perspective. One of the challenges is to determine the best venue and time to schedule these workshops. This is an area that we will continue to explore and develop to match our time & resources with teachers' schedules. We are targeting the San Francisco Bay Area during the pilot phase of our program development to make it relatively easy to provide follow-up visits if needed.

Fig. 3 Teacher Workshops - Environmental and physics science teachers at Alameda High School learn how to use the Solar Technology Kit to teach about solar electricity.

While a full (sunny) day workshop is ideal, our aim is to offer a range of workshop offerings so that we can adapt to teacher time constraints.

We are also working with Santa Barbara partners (Community Environmental Council, SB County of

Education, and UCSB) to establish workshop offerings at which teachers can earn professional development credit. Discussions have also begun with Cal State Hayward toward the same goal.

2. <u>ELEMENTS OF THE PROGRAM</u>

The components of the Solar Schoolhouse program are described below.

2.1 <u>Energy Technology Kits</u>

The solar technology kit has evolved from the teaching experiences of Hal Aronson and Tor Allen at middle and high schools. Via a hands-on approach, students learn about how electricity is produced, parallel/series wiring, power/energy, and get a feel for what volts, amps and watts are. We have developed a metering panel which we call the "Solar Power Monitor"(Fig. 3). It is a console that allows for various energy inputs: a) single 12VDC photovoltaic panel, b) 2 or more 12 VDC PV panels in parallel, c) several 3V DC PV panels in series, or d) a hand crank generator. On the other end, various loads can be powered including: a) water pump, b) light bulb, c) muffin fan, or d) a fuel cell. All of the energy input sources are either sunshine or 'people' powered. A variety of worksheets are included with the kit Solar geometry, conversion efficiency, shading and orientation effects on performance, are some of the exercises.

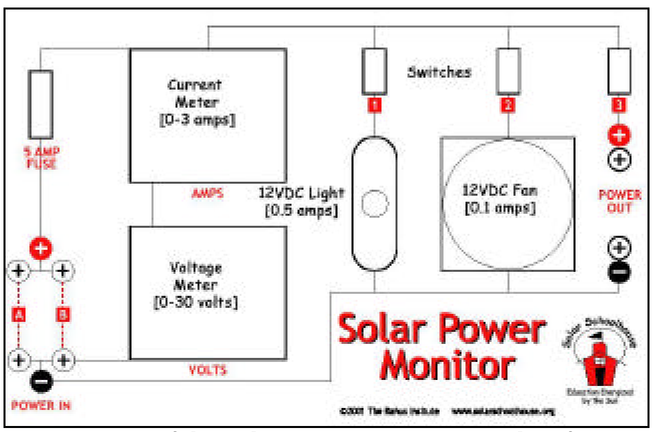

Fig.3 Layout of the Solar Power Monitor console – for ease in electrical measurements. The Power Monitor has built-in analog Volt/Amp meters along with a small lamp and fan to power. A Power Out port allows for powering other devices, such as a 12VDC water pump.

A large number of off-spec photovoltaic panels were donated to the program. Several of these panels are included with each kit. The first kits using the Solar Power Monitor are being piloted Winter/Spring of 2002. Initial feedback has been very positive.

2.2 <u>Energy Audit – Schools and Home</u>

One of the great lessons of solar electricity is that it's cheaper to save a kWh than it is to produce it. The 10,000 plus homes in California that are powered by solar electricity, are also energy efficient. The first step in designing a solar electric home is to conduct an energy audit and take steps to improve efficiency. A general rule-of-thumb is that a dollar spent on energy efficiency saves $4 worth of solar electric equipment. Many solar electric applications have become cost-effective because of improvements in energy efficiency of a technology. For example, emergency roadside call boxes are powered by solar cells because of advances in cellular phone technology. Portable construction signs nationwide are now powered by solar cells, instead of diesel generators, because of advances in LED lighting technology. The discussion on solar energy for home use naturally includes a lesson on energy efficiency.

We are currently piloting several home energy audit exercises for middle and high school. Audits include the use of a kWh plug load meter. These exercises reinforce the basic lesson of kW vs. kWh or Power vs. Energy. Understanding the units of energy and how to read our utility bills is the first step to becoming more energy efficient. Several schools will conduct audits of their own school, including monitoring the performance of a solar pool heating system at one high school.

2.2.1 <u>kWh Plug Load Data Loggers</u>

Two data loggers are available to measure the Power and Energy consumption of household appliances. The meters can be used for an in-class lab exercise or as part of the home energy audit. The use of meters/data loggers improves understanding of kilowatts and kilowatt-hours. The P3 Killawatt Meter will be packaged as a set ready for in-class lab, while the Brand Digital Power Meter is available as an option for classes that wish to record data and plot the results out in an EXCEL spreadsheet (Fig. 4).

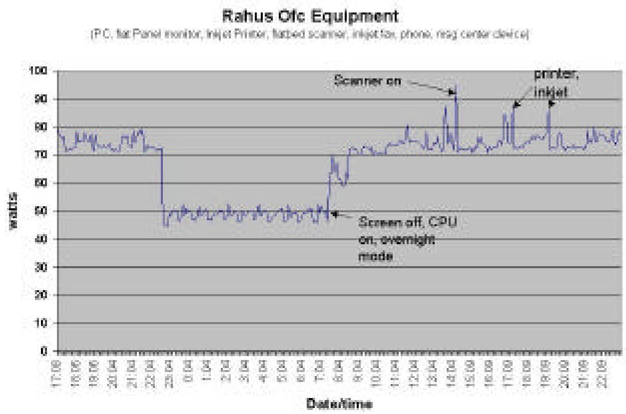

Fig. 4. kWh Plug Load Meters - Top) P3 Killawatt Plug Meter; (Middle) spreadsheet graph generated from data collected by data logger; (Below) - Brand Power Meter – data logger w/PC interface

2.3 Grid-tied Solar Electric Systems for Schools

A recent study[1] indicated that solar electric panels on school rooftops in California could produce 1500 Megawatts of electricity! Our first step to reaching this potential is to help install small working systems at many schools. Combining our hands-on lab experience with a real working PV system will strengthen the experience and impact of our program.

Pre-engineered 1kW PV kits are available at discounted prices. Each system will be connected to the utility grid and represent the same components that would be installed on a residential home.

Fig. 5 Women from a Solar Energy International solar installation workshop hoist solar panels at Lincoln Middle School in Alameda. Not only will the solar system have a lasting impact, but the process in which it was installed, provided an educational experience.

A data monitor records the performance of the system and students can conduct analysis via a local computer. Each school will be able to upload monthly data files to a website such that they can share & compare data with other schools around the state and country.

Installing the solar system will be the responsibility of the school. Solar Schoolhouse will provide step-by-step checklists for installing systems - from 1kW to 1 Megawatt. The systems can be mounted on poles, on the sides of the buildings (awning-like), or located on the school's rooftop. A key component of a grid-tied system is an educational display letting visitors know that the system is working (they tend to be quiet, with no moving parts). A dial-type utility kWh meter is an effective communicator, together with a poster display. As a side exercise, students learn how to read a dial-type utility meter – which is the kind typically found on their own homes.

While the magic of photovoltaics is best understood via hands-on direct power experiences, grid-tie systems serve an important function. They provide a physical reminder that this technology has graduated from powering calculators and wristwatches to powering our homes and schools. Installing a PV system at a school can also create a lot of media attention and provide a focal point for the surrounding community. At Lincoln Middle School in Alameda, the installation of a PV system inspired a month-long series of solar-related events at the school.

The installation of a PV system can also be an educational experience. At Lincoln Middle School, women from a Solar Energy International solar installation workshop helped install the system (Fig. 5)

2.4 Design Guidelines for Schools

Rahus will be working with the Collaborative for High Performance Schools (www.chps.net) to update the photovoltaic section in the design guidelines to include more information for schools interested in how to install PV system. There are several approaches that are being developed and tested. We are looking to share successful models that can be replicated at other schools. In addition to financial challenges, solar school projects in California pass through the Division of the State Architect (DSA) for approval. Documenting the details of this process and sharing this information will help to accelerate the installation of PV systems at schools.

2.5 Special Projects

Several schools have expressed an interest in going beyond the base curriculum. For these motivated students we aim to support and assist in conducting special projects. For example, San Ramon Valley High School, one of our pilot schools, is eager to build a solar electric car (one that you can actually ride in!). We are providing them with solar cells, modules and advice. Additional projects proposed at SRVHS include an audit of their solar pool heating system and a daylighting retrofit on the industrial arts shop. At Alameda HS, we are discussing partnering with a school in a developing country to provide a solar electric system (w/internet capabilities). A solar water fountain and solar hot water heater for the school garden, are some of the ideas surfacing at other schools that are in our pilot program. Many teachers just needed a little direction and some consultation to get them off and running with engaging projects. Many of these projects, especially the stand alone solar electric applications, require an analysis of the load they will try to power – providing an additional lesson in energy efficiency. We will document as many of the special projects as possible, posting them on the web, as a way to illustrate potential projects for others to consider.

2.6 Posters

We've had success with our SunPower poster (Fig. 6) in providing consumers and students with a visual poster-format learning tool. With the elementary school classes we discovered a need to develop a poster that highlighted various solar and energy efficient features of "your home". By using the home as the center of our discussion, we can bring the various technologies together and present it in an integrated fashion. Teaching a solar energy class to elementary school kids this past Spring and Summer reinforced the desire to have such a poster in our resource kit. The 'Solar House' poster is currently being designed.

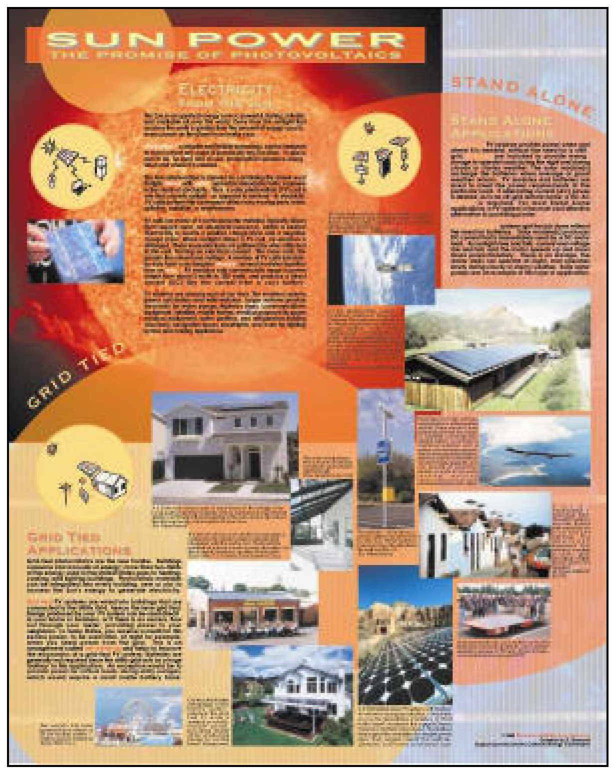

Fig. 6 SunPower Poster – The Promise of Photovoltaics

2.7 Reference Library

The Solar Schoolhouse Reference Library is essentially a starter kit for a renewable energy section in the school's library. Several books, CDs, videos, and other publications are provided to the school. We understand the value of having physical books on hand vs. being completely online dependent for materials.

2.8 Website

This past year (2001), we designed and established californiasolarcenter.org, a website intended to be a prime source of information regarding solar energy issues in California. Our weekly news digest, Solar e-Clips, has grown to over 1500 subscribers. We've learned a lot about what makes a website useful to visitors and have leaned toward keeping it simple.

Solar Schoolhouse will have a dedicated website [www.solarschoolhouse.org] to support the program. Features we intend to include are: web page per school, discussion page for teachers/students, data upload for schools with PV systems, lesson plan download option, additional links for special projects (eg. a solar car section) and other topics (eg. how to conduct a energy audit online).

3. CONCLUSION

Our experiences thus far, indicate that the hands-on component of our program has the greatest impact. Making electricity from sunlight, cooking food with the sun, designing and building kinetic art sculptures that move solely fromthe power of the sun…these are experiences that awaken a latent desire to learn more about energy issues. Our initial assumption was that each school had to have a grid-tied photovoltaic system, but now think that it's more important to provide the basic hands-on experience and allow for the development of special projects. A grid-tied PV system can be one of the special projects, as it provides a real world example of how solar energy can power our homes and schools. Lastly, our goal is to introduce a set of curriculum exercises that teachers adopt as their own and repeat every year. That will be the true measure of success.

4. ACKNOWLEDGEMENTS

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[1] Local Government Commission www.lgc.org