Promoting Renewable Energy in the U.S. through Education, and Applied Research

R. Rogers [1[1]], T. Chester

Abstract

The goal of the presentation is to provide a unique opportunity for teachers, architects, engineers, engineers, and contractors to teach green building principles and zero-energy home construction on a live "real time" WEB based operating house. The site is designed for learning and training their clients and students in zero-energy home design. A syllabus for teachers and professionals at all levels will be available on the site to walk students and clients through the sustainable technology principles of the home. The paper presents the opportunity to interface with an operating zero-net energy home in Portland, Oregon.

Introduction

The Rose House is the name of the site used for this teaching demonstration. The house is an 800 square-foot "green" cottage in Portland, Oregon. As one of Oregon Department of Energy's (ODOE) demonstration homes, the Rose house will annually generate more energy than it consumes. The 3.3KW photovoltaic array generates enough electricity to power all of the house energy consumption devices including heating, lighting and electrical loads. [3]

The home was designed by SERA Architects and is one of three zero-net energy home projects with instrumentation and control systems supported by the Oregon Department of Energy, the Oregon Renewable Energy Center, Environmental Control Corporation of Portland and Alerton Control, Inc.

"The Rose house goes beyond green building. It utilizes ideas and methods that lead toward truly sustainable architecture such as energy generation, zero green house gas related energy impacts and low toxicity materials." – Clark Brockman, SERA Architects

Figure 1. The Rose House

[1[1]] Robert Rogers, Oregon Renewable Energy Center, Oregon Institute of Technology

[2[2]] Christopher Dymond, Oregon Department of Energy

The technical elements incorporated into this house design allow the heating, cooling and ventilation system to be based around the use of a solar-enhanced heat pump water heater and a variable-speed energy recovery ventilator. The system design minimizes energy consumption by harvesting or rejecting heat when it can be done with greatest efficiency, rather than when heating or cooling is needed.

The goal of the project was to use easily replicable construction techniques to achieve a green building design with no net annual energy use and for not more than 115% of conventional comparable costs

The Oregon Renewable Energy Center and Environmental Control Company of Portland have installed an Alerton computer data acquisition and control system that will monitor eighty points of data during the operation of the house and minimize the amount of energy required. The system uses Alerton WEBTalk software to extend the results of the system to the World Wide Web. WEB displays have been created to make the data easily understood.

Real-time information on the solar energy generated at the site is compared to energy use by power loads. The data energy totals are presented to prove the claim of a net energy producing house. Other on-going research on the house can be followed by observing the temperature profiles of the solar plenum or the radiant heated floor. Data points throughout the heating system demonstrate the super-high efficiency heating equipment design.

“The Rose House is a prototype power plant,” says Christopher Dymond of the ODOE. “It generates power during the daytime when the owners are at work or play. Our electric energy grid is becoming much more like the Internet – a distributed network of power plants (large and small) all working together to meet our energy needs.”

The project is part of ODOE’s High Performance Home Initiative. The goal of this work is to lay the groundwork for the next generation of homes that integrate green building strategies, super insulation and onsite renewable energy systems. The project is intended to develop builder expertise, foster the emergence of new technologies and demonstrate the net energy home concept, where homes generate as much energy as they use annually.

“This type of home is very affordable while containing all the typical amenities of a comfortable living environment,” says Charlie Stephens of the ODOE. “The home’s integrated design actually creates a superior environment with better indoor air quality, enhanced lighting, consistent temperature control and a quieter interior than a conventional residence.”

The Zero-Energy Solution

The ability of the house to be zero-energy is primarily dependent on three elements:

- Advanced shell design
- Super high efficiency heating system
- Photovoltaic (PV) power generation

The three elements work in unison and are required to create as much energy as is consumed in a viable economic package. The design team was committed to using easily replicable construction techniques that could be accomplished for not more than 115% of conventional construction cost. A key element of uniqueness to the Rose house is that in addition to demonstrating technical innovation, it is all about affordable and appealing design that is accessible to the general population.

The advanced shell design serves to minimize the heating and cooling requirements of the home. A Structurally Insulated Panel System (SIPS) is used for the roof. A Staggered Stud System is used at the walls with recycled blown cellulose insulation (R-25) allowing continuous insulation around the studs and providing a breathable vapor barrier. Special foundation insulation details minimize temperature changes.

The Super High Efficiency space conditioning system uses less than half the energy of a conventional system while providing fresh air and eliminating the need for a furnace in favor of a solar heat pump. [2] The heat pump gathers energy from the back of the PV collectors and generates energy as hot water. A 120 gallon thermal storage tank stores the hot water which is then pumped through the house for heating. A clearstory bank of windows provides generous day-lighting and natural stack effect ventilation instead of air conditioning.

The 3.3KW Photovoltaic Array of Sharp solar PV panels is a grid tied system that provides more energy than required at times and less than required in others. The grid acts as a big electrical storage bank that is required to make the house function properly. During start-up of motors and electrical equipment much more than 3.3 KW is required and the grid provides that extra capacity.

As seen by the following diagram, overall during the year, the house will supply more energy to the grid than it has consumed. Since all appliances and the heating systems work on electrical energy, the house is a Zero-Net Energy house. Solar PV power is the blue contribution below the line and the various household loads are above the line.

The diagram is a computer model of this house. The WEB site will show a daily and accumulated graph of. The actual energy delivered by the photovoltaic grid and the household energy loads.

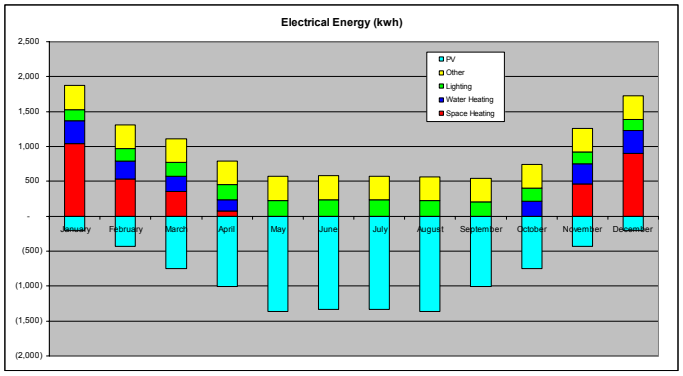

Figure 2 – Rose House Energy Generation and Consumption

The Cost of a Zero-Energy Home

The first cost of a "zero-net" energy home can be reduced to near that of a typical house. Some of the component cost savings were possible because of new energy recovery technologies. The majority of the cost savings however, came from a design that gets multiple benefits from each feature. These design elements and their relative cost savings will be presented. [1]

- Envelope design with highly insulated staggered stud wall system allows loads to be met with airflow rates provided by the fresh-air ventilation system.
- Use of a heat pump for domestic hot water heating, space heating and space cooling.
- Use of an energy recovery ventilator to provide humidity-optimized fresh air and serve as a primary driver for the heating coil, energy recovery and economizer function.
- Use of concrete slab construction to serve as thermal storage both passively (direct gain) and actively (heat pump).
- Use of PV array to provide a source of waste heat, reduce cooling loads and improve roof life, in addition to providing all of the annual energy requirements for the house.

Preliminary results indicate that the additional costs of the house from these features will be less than 15% - including the net cost of the PV system after incentives and tax credits in Oregon.

Integrated Energy Systems

The core of the house heating system is its "Solar Heat Pump" which uses a heat pump water heater (HPWH) to provide domestic hot water, space heating. The solar heat pump uses waste heat harvested from beneath the photovoltaic array to enhance the heat pump water heater's heating efficiency. Removing the warm air from beneath the PV array may also increase the efficiency of the PV array.

To optimize daily energy collected, the heat pump operates when the air under the solar collector is at its warmest. The energy collected is stored as hot water and as heat in active solar heated portions of the concrete slab floor.

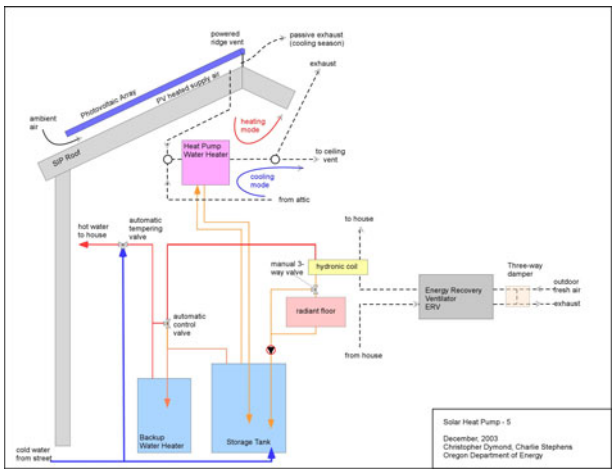

Figure 3 Rose House Mechanical System

During the cooling season, the heat pump can be used to provide cooling to the space while heating water for domestic use. The warmest air inside the home can be drawn through the heat pump evaporator, cooled and delivered back into the space. This will provide roughly 48,000 Btu of cooling per day, which is sufficient to meet the design cooling loads in Oregon, while at the same time heating water for domestic use.

Using This Project to Teach Sustainability

The WEB address for the Rose House Solar site is http://www.oit.edu. Once at this page click on the link for the Oregon Renewable Energy Center and then the link for the Solar Rose House. At this point you will be viewing the Solar Rose House site.

The site will provide a description of the features that made the house energy independent. It will also present the construction features that make it “green” and sustainable.

The “real time” energy information will compare the amount of energy consumed by the household loads and the amount gained by the solar PV system. A total to date during the year will be graphically presented. The site will also keep a running total of the energy saved to that date during the year as compared to a code standard house and the dollar savings,

You may select the area that you wish to learn or to teach from. It is hoped by the authors that teachers in the K-12 grade levels across the country and teachers in higher education will begin to teach “green” with this operating and interactive house.

Teachers can use the site for all levels of teaching energy saving and green building fundamentals. The elementary site will contain links to children’s energy learning sites such as the Oregon Department of Energy link for kids. http://egov.oregon.gov/ENERGY/KIDS/Kids.shtml

Figure 4 ODOE Fun Links for Kids

High school teachers can demonstrate the house from a basic physics approach. The site will contain links to teach social responsibility such as the EPA global warming site for kids. http://www.epa.gov/globalwarming/kids/.

The site will contain links for teachers to curriculum for energy learning such as the Alliance to Save Energy Web Site. http://www.ase.org/section/_audience/educators/lessons/

Higher education and professionals can use the site to present energy solutions and renewable energy opportunities. The professional site will demonstrate the considerations and choices that are necessary in working towards "green design" in a home. The operating characteristics and real-time energy benefits will be demonstrated. Links will be made to support for energy professionals.

The site for professionals will allow a much more extensive look at the building operating systems. The site will present the conditions required for control and operation. The site may be used by higher education physics and engineering classes in understanding the thermodynamics of zero-energy home building systems.

It is hoped by the authors that schools across the country and perhaps the world will recognize the value of this real-time zero-energy learning laboratory. Boise State University and Oregon Institute of Technology will use the house as a laboratory for engineering student's experiments this spring of 2005. Perhaps the Rose House site will become a co-operative laboratory for studying "zero-net" energy concepts across the country.

The mechanical system equipment contains sensors and monitors throughout the house that can allow architects and designers to help understand the characteristics of "green" building materials. Sensors are located across wall sections to see the comparative thermal benefits of highly efficient insulated wall systems and radiant floor heating systems.

The extent of the complex series of sensors and automated controls can be seen in the following figure. All of the mechanical systems described in previous sections of the paper are completely monitored for performance.

A new four-year Bachelor of Science Degree program in Renewable Energy Systems (R.E. S.) has been instituted at the Oregon Institute of Technology. The program will serve as a model for R.E.S. programs across the country. [4]

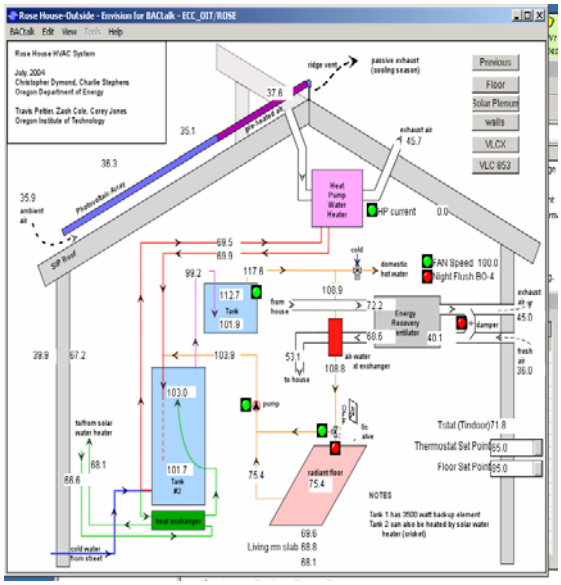

Figure 5 The Rose House Professional's Screen

The Engineering Team it Took to Make this Site Available

To make this house available as a real time teaching tool took all of the latest cutting edge computer technology and a team of engineering experts. The sophistication of the control and monitoring system of this house is on the order of that provided for Bill Gate's house.

This achievement was accomplished by a team of engineers volunteering their time and unique knowledge to create an automated house that can be viewed right from your house on a computer. These engineers spent evenings and weekends and their vacation time to provide the capability to do this. This section describes the behind the scenes work that took place to make this unique opportunity available as a free educational tool.

The major brunt of the engineering computer automation work fell on the shoulders of Environmental Control Corporation of Portland, Oregon (ECC). This group of engineers provided the technical expertise to make the Alerton computer controlled system work.

The computer monitoring and control system was provided by the support of ECC and Alerton Controls, Inc., a subsidiary of the world-wide Honeywell Control Systems Company. The computer control system that they developed for this project monitors and controls all of the mechanical system for the house and many of the wall and floor performance characteristics.

The computerized monitoring and control system consisted of an Alerton global control card (VLCX) and several local computer cards (VLC). These cards allow the input and output of computer controlled signals to automate the functions of the house and log the data that is gathered.

The Rose House has eighty inputs and outputs to the computer cards to perform this task. The house is monitored remotely and interfaced to the WEB by the functions of the global control card.

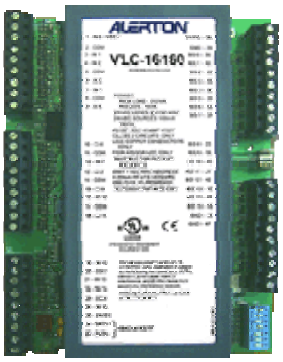

Figure 7 Rose House Computer Control Cards (VLC)

Most of the computer interface work was provided by computer programming engineer Kent Stidham. Kent has worked for ECC for 8 years and now is their go-to guy in customer support. Kent spent endless hours of donated company and his own time coordinating the computer automation with all of the functions of the "green" building. Kent's favorite quote throughout the project was "I am there for you". Kent worked for eighteen years in the nuclear power industry before moving into the computer automation field with ECC.

Tom Mahrer is the area sales manager for ECC and was instrumental in designing the Alerton control system used in the house. Tom was the ninth person originally hired in the Alerton Company which went on to become one of the leading building automation systems companies in the world. Tom had the responsibility of providing an Alerton integrated computer control system for the city of Tucson.

Dick Schweiger is the owner of the Environmental Control Company and with his lead provided the go ahead and company support for the donated development of the Rose House control system. Another key player behind the scenes with ECC was Cliff Nielsen, sales manager. He integrated the project and solicited the contributions needed to complete the WEB access.

The Environmental Control Company was capable of providing sustainable building expertise because of their extensive experience in automated control and "green building" system design. Environmental Control Corp. was founded in 1987 to eliminate control/equipment problems for mechanical and construction contractors who were purchasing temperature control and mechanical systems from separate vendors. Since then, they have become one of the largest system designers and control contractors of building temperatures control, automation and service in the Northwest.

One "green building" that ECC was recently was involved in developing the automation system for was the new $45 million Kelley Engineering center on the campus of Oregon Sate University. Built to LEED (Leadership in Energy and Environmental Design) "Silver" (2.0) specifications for sustainability, the Kelley Engineering Center's many "green" building elements will be used to educate students and others about sustainability and renewable energy issues, before, during, and long after construction.

Figure 6 The Kelley Engineering Center

Another important team player for the Rose House project was the Alerton Control Company of Redmond, Washington. Alerton is a pioneer and an industry leader in providing building management solutions for heating, ventilation and air-conditioning equipment for all types and sizes of buildings. We also provide building management by integrating fire, life safety, lighting, access management and other building systems.

Alerton and ECC shared the donation of the server that is required to integrate the control system to a WEB interactive tool. The recent development of this technology by Alerton is the key to being able to share with anyone anywhere the feature of a project like the Rose House. This new Alerton Technology is called WEBTalk.

The WEBTalk server is located in an Alerton computer network that resides on the Oregon Institute of technology campus in Klamath Falls, Oregon. When you view the Rose House on the WEB you are actually seeing the data coming from the house overlaid on a viewing page of the OIT network server. The WEBTalk server then translates the pages residing on the network server into an HTML format that can be interactive on the WEB.

Teachers, engineers, architects, contractors and students can now use a standard Web browser to monitor and control critical building automation data and interact with a house such as the Rose House.

Conclusion

The model is now available to build “green” net-zero energy houses in the U.S. at 15% over standard construction costs. The technology to show the feasibility of these concepts is now available to anyone with WEB access.

This new technology allows the next generation of energy users to learn about energy and sustainable responsibility anywhere. The challenge of this paper is to ask the question “who has the responsibility to teach this next generation?”

References

[1] Arya, R and Rogers, R, Opportunities in Thin-Film Photovoltaics for Net-Zero Energy Residential and Commercial Applications, ICORE, India, 2005.

[2] Rogers, R and Dela, R, Photovoltaic Powered Residential and Small Commercial Heating and Cooling Systems, Proceedings, NSEC 2004, Portland, OR 2004.

[3] C. Dymond, C, Rogers, R, Brockman, C, Low Cost Zero Net Energy Home Design using a Solar Heat Pump, Proceedings, NSEC 2004, Portland, OR 2004.

[4] Yarbrough, J, Bachelor of Science in Renewable Energy Systems, Proceedings for ISEC 2005, Orlando, FL.