A DIRECT SOLAR WATER HEATINH SYSTEM FOR THE HEALTH CLINIC IN THE TOWN OF SANTA ISABEL CHOLULA, SATE OF PUEBLA, MEXICO

Roberto Rosas-Romero
Department of Computing, Electronics and Mechatronics
Universidad de las Américas-Puebla
Santa Catarina Mártir
San Andrés Cholula, Puebla, México 72810
Email: Roberto.rosas@udlap.mx

Jeffrey S. Tiller
Department of Technology and Environmental Design
Appalachian State University
Katherine Harper Hall
Boone, NC 28608
Email: tillerjs@appstate.edu

Brian W. Raichle
Department of Technology and Environmental Design
Appalachian State University
Katherine Harper Hall
Boone, NC 28608
Email: raichlebw@appstate.edu

ABSTRACT

Solar water heating technologies have the potential to provide tremendous cost and emission reductions, particularly in climates with little or no freeze potential. Further, access to hot water enhances sanitation and comfort. We present, as a case of study, a direct solar water heating system installed by an international collaboration including Universidad de las Americas Puebla and Appalachian State University during the summer of 2011.

Thermal performance data will be reported, as will lessons learned while undertaking a project in rural México. . A preliminary analysis suggests a 50% reduction in natural gas consumption. The possibilities for widespread adoption of such technology will be explored, and estimates of potential energy and cost savings will be investigated.

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1. INTRODUCTION

Renewable energy is obtained from natural resources such as sunlight, wind, movement of sea waves, and geothermal heat; all of which are renewable as opposed to hydrocarbons. Of course, increasing worldwide energy consumption of hydrocarbons is a primary cause of pollution, damage to the environment, and global warming.

The use of energy is not balanced since there are places where energy is overused, while other places lack the necessary energy for a good quality of life such is the case of rural communities in Latin American countries. Therefore, it is important to provide isolated and remote sites with the means to harvest their renewable energy resources (1). The primary needs of energy in a community, of such characteristics are hot water, lighting and electricity with purposes of education and medical services (2). The best solution to these problems in rural communities in México is the use of solar thermal technology, photovoltaic systems and wind generators.
This paper describes a model by which rural communities can be provided hot water via solar thermal technologies.

The Community of Santa Isabel Cholula, in the State of Puebla in México, has geographical and climatic conditions ideally suited for the use of solar radiation. It is a rural community with needs and it is one of the most isolated places close to the city of Puebla in México (the fourth largest city in the country). The population is composed of 1,803 inhabitants. Citizens of Santa Isabel Cholula and others living in rural parts of the State have to travel to Puebla for services such as medical care.

Faculty and students, from Universidad de las Américas-Puebla in México and Appalachian State University in Boone, North Carolina U.S.A., participated in a project to design, build and install two systems (photovoltaic and thermal solar) based on the use of solar radiation for heating water and supply electricity in a community building for a population in a rural community near UDLAP's campus. A photo of the clinic is shown as Figure 1.

Fig. 1: Health Clinic at the Community of Santa Isabel Cholula in the State of Puebla in México before the project was undertaken.

The supply and installation of a photovoltaic system was composed of a DC battery and a solar panel for electric power generation with applications in nocturne illumination at the health clinic. The monthly average electricity consumption of the clinic was 333 kWh during 2009 and 264 kWh during 2010. The introduction of lighting at night times is possible through the storage of energy in batteries that are charged during the day by photovoltaic panels. The lights can be controlled automatically by use of a light sensor. The design and implementation of this system was entirely done by students and faculty from both institutions at very low cost. The project is intended to provide considerable savings for the clinic's energy budget.

Although the project involved photovoltaic technology; the topic, described in this paper, focuses on the design, construction and installation of a solar thermal system for heating of water at the health clinic to replace previous gas heater. The clinic has a full-time staff (physicians, nurses and patients) that sleeps in the clinic and requires the domestic hot water for showering and other basic needs. Monthly expenses at the clinic for gas consumption to provide hot water and cooking ranged from $1,100 to $1,350 Mexican.

2. REVIEW OF ANALYSIS AND STUDIES

Analyses were carried out on the feasibility of achieving the project objectives based on the climatic conditions of the location, which is 2,100 meters in altitude, and the position and orientation of the building for efficient collection of solar radiation. As a consequence of the analyses, the student and faculty team decided to design and install a solar thermal system as support and complement to the previous gas heater. Although solar radiation alone is required to heat the water during summer and spring time, having both systems working together is important at winter times.

To improve heating of water, systems must be sized according to the highest hot water flow to be operating at full capacity even during times of very high demand. As a result, a 200-liter storage tank was used. Pressure on the hydraulic system is exerted by an existing 500-liter cold water storage tank placed 2 m above the hot water storage tank, which substituted for a typical pumping system used in solar thermal operations.. As a consequence, the project provided savings on both natural gas and electricity.

The students from both institutions participated in several joint teleconferences via the Internet to design the solar thermal and photovoltaic systems. The teams developed different solutions, priced the materials, and charted the anticipated schedule.

The final cost was compared to that for commercially available solar thermal systems. The team discovered that several solar thermal systems were both cheaper than the cost estimate for the materials of the system that they designed, and also was easier to install.
The final system selection was a system with combined evacuated-tube solar thermal collectors and built-in thermal storage. The students estimated that 24 evacuated tubes of borosilicate glass which were 47 mm in diameter and 1.5 m in length would be adequate for heating 200 liters of water per day at a temperature of 70° C under normal conditions of solar load.

The evacuated tube system was coupled to the hot water storage tank through the use of a supporting steel structure pre-manufactured and adjusted at the Laboratory of Mechanical Engineering at Universidad de las Américas-Puebla. Final production and adjustment of the steel structure was based on the inclination of the roof and average orientation of sun over the year.

To provide a cost-effective and user-friendly heating system at different conditions, a thoughtful combination of valves is introduced so that the system can work and be operated by the clinic staff by using both heaters (gas one and solar one) or the solar one alone which is the purpose of taking advantage of the climatic conditions of the place.

Sensing was also considered to comply with the significant constraint of keeping water temperature, especially during summer times, not exceeding levels harmful to human skin. Installation of mixing valves was the solution in this case. Documentation of the project included a manual of operation to help people at the clinic to provide the system with maintenance.

Improving the economics of the project execution, even at small scale, is important since this model will be easily replicated by people living in the community near the health clinic. This project also provides the motivation for the use of "green" energy as well as the economic development and revenue to local municipalities. Students from both universities performed the final installation of the systems, and demonstrated plumbing techniques as another positive benefit of the project to the authorities of the clinic and the people of Santa Isabel. A sketch of the thermo-siphon system used is illustrated in Figure 2.

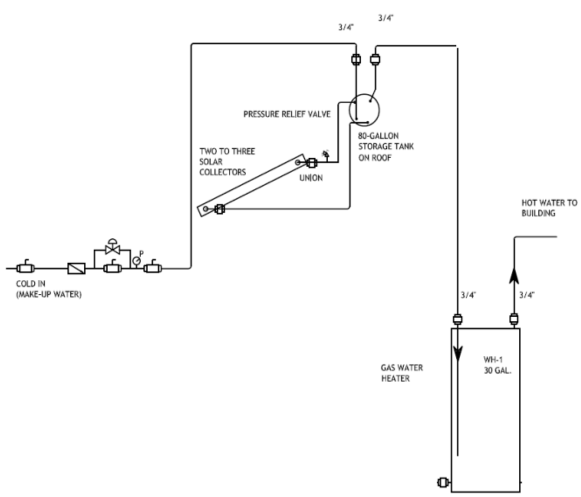

Fig. 2: The solar thermo-siphon system.

Monitoring of the flow of hot water coming out from the solar thermal system shows that more than half of the flow of hot water for current use at the clinic comes from the solar thermal and these results are confirmed by a 50% savings in bills for LP gas consumption.

3. METHODOLOGY

The project arises was executed in two stages. The first stage consisted in the study of feasibility: Studies and various analyses that should be made to prepare the installation of systems offered in 10 working days which was the length of the stay of the visiting students from Appalachian State University. Collaboration between the people from both universities was possible through videoconference sessions with one conference every week during almost three weeks. During all this time challenges, faced for planning and execution of the project, were solved through the skills and experience of faculty and students from Appalachian State University since its curriculum includes a class on Solar Thermal Design where students have to design and build one of these systems to work under extreme conditions such as snow.

The design, construction and commissioning of a thermal system for heating of water in the clinic of Santa Isabel took place in the second stage. The selection, funding and acquisition of equipment and accessories for construction and installation were a real challenge: evacuated tube collector of 1.2 m × 0.9 m, platform mounting, tank with capacity for 200 liters of water, drip valve for protection against freezing, 10-W photovoltaic panel, relief valves, check valves, tempering valves, copper pipe and unions, manometer, flow meter, etc. Table 1 shows the sources of funding for the project as well as an estimation of the costs.

TABLE 1: CONTRIBUTIONS MADE FOR THE PROJECT

Contribution	Contributor	Estimated Value of Contribution
Solar thermal system for heating of water	Funding coming from the National Council of Science and Technology in Mexico	$790.78 USD
Photovoltaic System for generation of electricity	Materials and accessories donated by the Department of Technology and Environmental Design at Appalachian State University; travel funds provided by USAID (not included to the right).	$500.00 USD

Other needs had to be solved such as travel allowance and transport, visits to implementation and testing and monitoring and follow-up of installation on the work site. Support for training of human resources and participation of students from UDLAP who were not previously involved in the use and management of this kind of technology was another major challenge,

4. RESULTS

One solar thermal system was designed and built to provide a health clinic of a rural community with hot water. The characteristics of the system are that it works with gravity, uses a hot water storage tank of 200-liter capacity and 24 evacuated tubes with the capacity to heat 200 liters of water per day at a temperature of 70° C under normal conditions of solar load.

Savings in gas consumption have been possible due to the introduction of this technology as well as an enthusiasm in the people of the community to take advantage of the renewable energy resources at their disposal. The town of Santa Isabel also has the geographical conditions appropriate for the implementation of electricity generators based on wind turbines.

Figure 2 shows the new systems under current operation. The installation took place from the 30th of May 2011 to the 10th of June 2011.

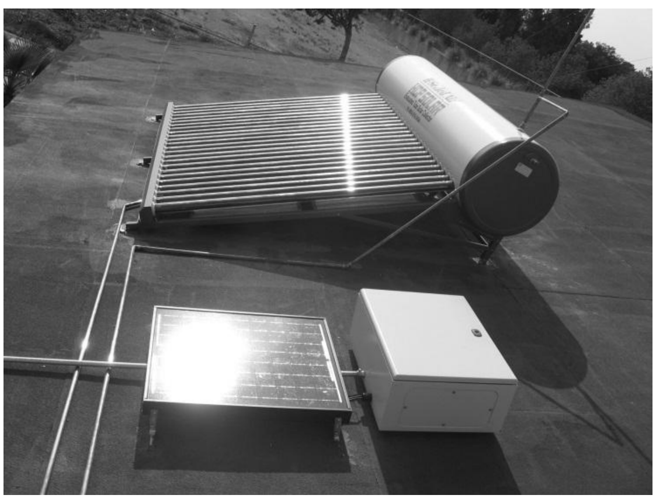

Fig. 3: Solar thermal and photovoltaic systems in current operation at the health clinic in a rural community.

5. SUMMARY AND CONCLUSIONS

The execution of the described project has had different impacts such as the improvement of the health services provided to the community as well as the work environment of staff that at the clinic. The reduction of the carbon footprint for the clinic has been possible through the introduction of technology for energy sustainability and the use of renewable energy. Another result is the training of professionals with skills to investigate and innovate in the areas of renewable energy, applied technology and sustainability of buildings. The project also laid the groundwork for research and application of technology in this area at Universidad de las Américas-Puebla, as part of the research projects to be developed in the future post-graduate program in renewable energies.

Another impact is the development and application of technology for efficient use of energy in rural areas, with applications in medical services and quality of work of public servants. The use of technology for energy sustainability also has an impact in remote localities with lack of essential services.

The introduction of this technology is reducing the operating costs of Santa Isabel Cholula.

The final impact is the reduction of pollution as a result of the clinic's activities and the awareness in communities about the efficient use of energy and the importance of achieving self-sustainability through the use of renewable energy. Santa Isabel Cholula is a community with geographical and climatic conditions for the use of solar radiation and even the force of the wind.

6. ACKNOWLEDGEMENTS

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The authors would like to acknowledge the leadership and participation in this project of municipal officials, faculty, students, including the Mayor and the Minister of Health at Santa Isabel Cholula, Miss Verónica Montes Pacios, for letting us work with them as well as providing us with information; Dr. Jesse Lutabingwa, Director of International Education and Development from Appalachian State University who was involved in the funding of the project; Nick Hurst, Associate Director of the North Carolina Energy Efficiency Alliance, who helped coordinate installation activities at the clinic in conjunction with UDLAP faculty; Sebastian Brundage and Tyler Davidson, students from the Department of Technology at Appalachian State University who were the people taking the lead during implementation and operation of the project and for visiting and helping this community and also for teaching UDLAP students how to work with these technologies; Dr. Dennis Schanlin for providing the solar panel and other components for the photovoltaic system; and 15 students from Universidad de las Américas-Puebla who help in the execution of the project.

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