Abstract

The purpose of this project is to design a solar system for a dormitory sized residential building, which produces both hot water and electricity for residential use. To achieve these goals I have chosen to use a parabolic trough solar concentrator system. While parabolic trough concentrators have been used for many large-scale solar thermal electric generation plants, there use as combined hot water and photovoltaic system (CHAP) is a recently emerging technology with only a few systems currently constructed; mainly in Australia by the Australian National University. This report outlines both the electric power and hot water production capabilities of a CHAP system designed for Santa Lucia dormitory on Cal Polytechnic SLO campus. This report will further analyze the lifetime economic benefits and costs of such a solar system.

Photovoltaic Troughs

Photovoltaic Troughs consist of two parts: mirrored parabolic troughs (concentrators), and the photovoltaic collectors. The mirrored parabolic troughs focus incoming solar energy onto a focal line, which runs the length of the trough. Photovoltaic cells are mounted along the focal line and collect the concentrated solar energy, converting it into electricity. The ratio between the troughs aperture width and the focal line’s width is called the concentration ratio. For this project a concentration ratio of 22 has been assumed based on standard parabolic trough designs. One major benefit of this system lies in the fact that relatively inexpensive mirrors are used to concentrate solar energy from a large area, and far less photovoltaic cells, which are very expensive, are needed to produce the same amount of electrical power. Because the amount of photovoltaic cells needed is 1/22nd the size of an equivalent standard PV system more efficient and expensive multiple sun PV cells can economically be used. The problem with any photovoltaic concentrator system lies in the fact that PV cells operate most efficiently at 30 degrees Celsius, and their efficiency drops off as the cell temperature increases. In a parabolic trough system, PV cells receive an equivalent solar energy as if from 22 suns. This intense solar energy produces cell temperatures well above 20 degrees Celsius and thus some sort of cooling system must be used to maintain efficient cell operating temperatures. Cooling is usually achieved through natural air convection over a cooling unit or by flowing cold water over the backside of the solar cell.

Combined Hot Water and Photovoltaic System (CHAP's)

Combined hot water and photovoltaic systems operate with the same idea as a cogeneration plant. This idea is to use waste low-grade heat energy from one system as useful heat energy for residential applications, usually either hot water or hydronic heating. If a water-cooling system is used in conjunction with PV troughs the resulting output from the system is both electricity and hot water. Hot water can be produced at a temperature equivalent to or higher than a residential hot water tank, while maintaining the PV cells at a reasonable operation temperature. By capturing the sun's energy in multiple ways a solar efficiency of 67% can be achieved by a CHAP system.