Low concentration photovoltaics

Carlo Vaccari
carlo_vaccari@hmc.edu
Advisor: Peter Saeta

Background

One of the most promising 'green' technologies is the use of solar power to produce electricity instead of burning fossil fuels. One of the most common ways to do this is with a photovoltaic (PV) panel. These use semiconductors to produce electric potential when exposed to light. They are relatively inefficient, and expensive due to the large amount of semiconductor needed to cover a large area.
To reduce this, concentrated photovoltaic (CPV) systems use optics to maximize power production for a given photovoltaic panel area. Because the price of solar panels is higher than the reflectors and lenses needed to concentrate an equivalent amount of light, the high cost of plain photovoltaic systems can be reduced. In addition, the reduced panel area allows the use of more efficient panels for maximized energy production per area of collector.
Currently, most development is in the form of high-concentration CPV systems, because of their potential for very high efficiencies, but they have the disadvantage of requiring tracking systems. These are motorized and need both advanced computer control and much more maintenance.
For this reason, many residential photovoltaic systems use plain PV panels. However, this is an expensive investment, usually many thousands of dollars, and few people have the resources and credit to purchase a system.
One possible way to alleviate this is by using low-concentration CPV systems. These can have high acceptance angles and require no complicated steering systems, allowing them to be within reach for residential customers, but they also are potentially much cheaper than plain arrays. They can be achieved quite simply, with a single mirror.

Objective

Develop a scheme to optimize low-concentration CPV systems using one or few flat mirrors and without a tracking system.

Tasks

Research existing CPV methods: 10 hours
Develop solar position calculator: 20
Develop mathematical model of a solar cell (based upon angle, shape, and size): 20
Develop mathematical model of a concentrator. 30 hours
Develop an optimization for cost and performance. 40 hours

Educational Value

This research project would allow me to practice my engineering skills in a practical manner, in a way I haven't been able to before. The independent research would also prepare me for work at graduate schools and in industry. In addition, I would have to learn mathematical optimization.

Significance of Research for Environmental Quality

The manufacture of solar cells is expensive, deterring the widespread use of them for green energy production. By reducing the area of solar cells needed with simple mirrors, the cost can drop dramatically, increasing the amount of solar energy production capacity that would be installed. This in turn can help reduce carbon dioxide emissions.

Proposed Budget
I expect to require 4 weeks, after Summer Math.

References
http://www.geo-dome.co.uk/article.asp?uname=solar_mirror
http://en.wikipedia.org/wiki/Concentrating_solar_power
http://en.wikipedia.org/wiki/Shockley-Queisser_limit