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IB Physics HL Internal Assessment

The Feasibility of Solar Power

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Computer Simulation

#9

# The Feasibility of Solar Power

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## Introduction

Photovoltaic (or PV) cells are able to convert electromagnetic radiation from the Sun into electrical energy. A single cell contains a crystal of semiconductor with two faces. When photons from the sun hit the cell, electrons are released from the n-type layer to the p-type layer and then around the circuit. One cell usually has an emf of only around 1 V so banks of cells are usually connected in a combination of both series and parallel circuits for practical use.

The total power converted by a panel is $\eta IA$ where I is the intensity of radiation from the sun, A is the area of the solar panel, and $\eta$ is the efficiency of the cell or in other words the percent of energy arriving that is converted into internal energy.

The benefits of solar power include low maintenance costs (after initial installation) and zero fuel costs. More importantly however solar power is a renewable resource. The earth will not run out of sunlight and solar panels do not emit greenhouse gasses. Solar panels will likely play a role in a more sustainable future for our planet. A few downsides to solar power include the relative inefficiency of solar panels and hence the need for a large area of them in order to produce adequate electricity. Another downside of course is the reliance on good weather.

My question is: What dimensions of solar cells would be needed for my house run entirely on solar power?

I am interested in this because I am a strong believer in saving the planet. If everyone used renewable resources like solar instead of fossil fuels, the world would be a lot more sustainable and the air a lot cleaner. Personally I would like to know if my house could be powered by solar power because if it could, perhaps one day my family will decide to make that change.

I hypothesize however that because of where I live, it would be impractical for my house to rely only on solar power. I think this because western washington is overcast and rainy for much of the year. I have lived here for my entire life however I know of very few houses or buildings with solar panels.

## Methods

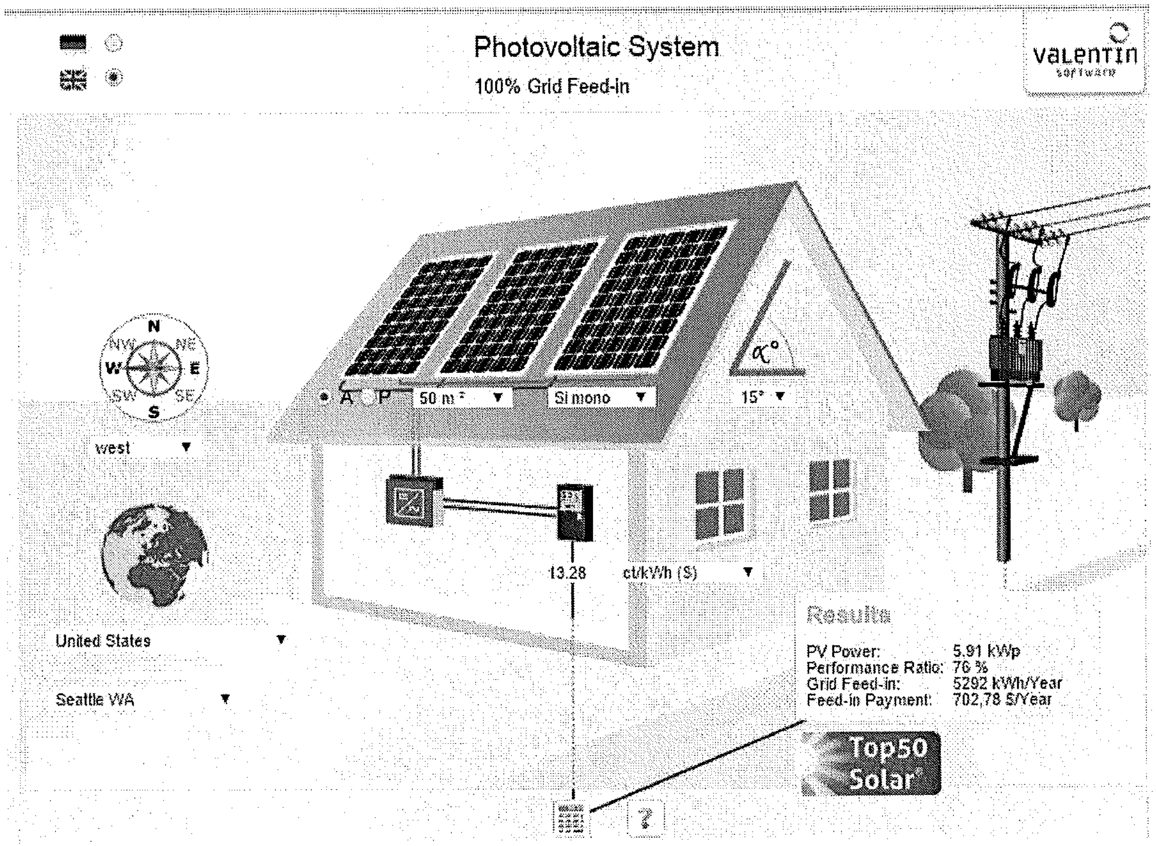
To answer my question conditions of my house such as the direction my garage roof was facing, the angle of the roof and the area available for solar panels was measured. The information as well as the name of the nearest big city to where I live was entered into a computer simulation. Data was collected for two different kinds of solar panels and calculate the area needed of each of these panels to provide power for my house. For purposes of replication see detailed steps below.

Materials:

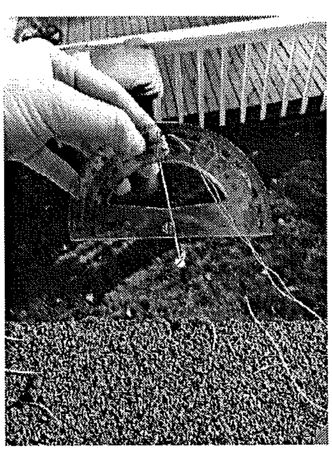
- Photovoltaic cell simulation
- Protractor
- Weighted String
- measuring tape
- compass

To answer the question, valentin software Photovoltaic System simulator was used to simulate the conditions of my house.

**Screen cap of simulation used**




**Measuring the angle of my garage roof**



A compass was used to determine that my garage roof was facing west and the plumb line and protractor to determine the tilt angle of my roof. Data was then imputed into the simulation along with my location in the world.

Data was collected on the area covered by solar panels vs the amount of power produced for two different types of solar cells.

This data was then able to be analyzed and compared to the size of my roof and the amount of energy my household uses to see if either type of the solar panel would be a feasible option for our needs.

The only safety consideration involved in the data collection process was that of climbing on the roof to measure its angle and area. It was addressed this by making sure the use of a secure ladder and proper footwear was employed reduce chances of falling.

## Results and Analysis

Raw data from simulation

| Table 1: Amorphous silicon cell | |
|---|---|
| Area (m^2) | Power kWh/year |
| 1 | 111 |
| 2 | 111 |
| 10 | 554 |
| 20 | 996 |
| 50 | 2545 |
| 100 | 5090 |
| 200 | 10070 |

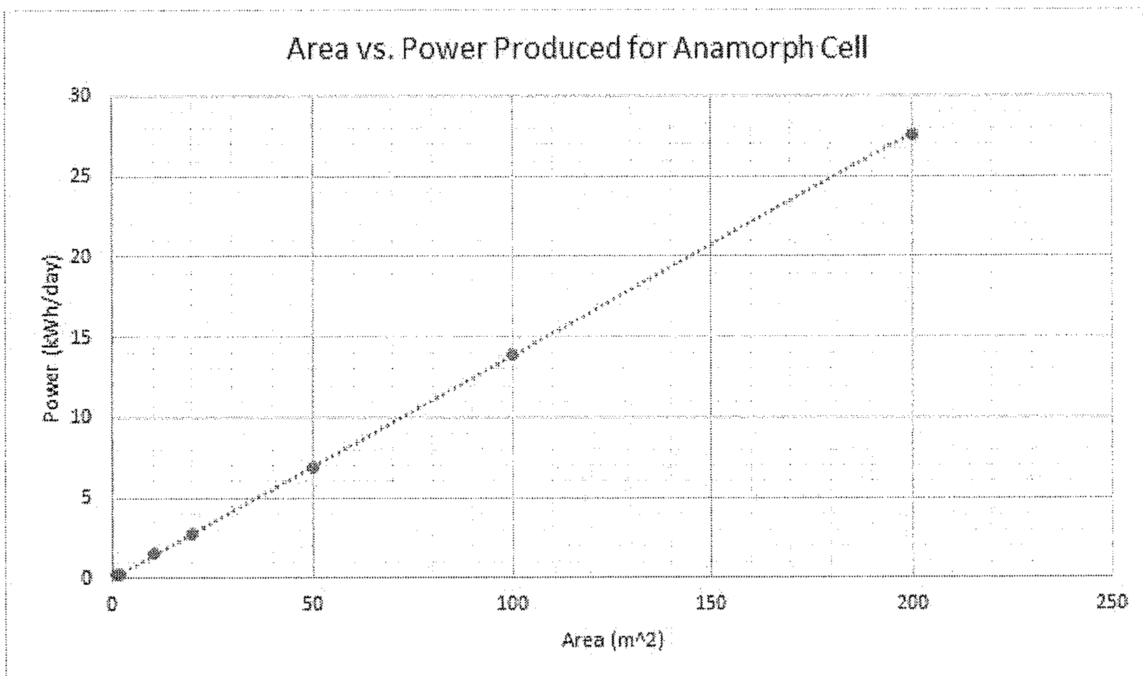
Converted to power per day

| Table 2: Amorphous silicon cell | |
|---|---|
| area (m^2) | Power kWh/day |
| 1 | 0.304109589 |
| 2 | 0.304109589 |
| 10 | 1.517808219 |
| 20 | 2.728767123 |
| 50 | 6.97260274 |
| 100 | 13.94520548 |
| 200 | 27.5890411 |

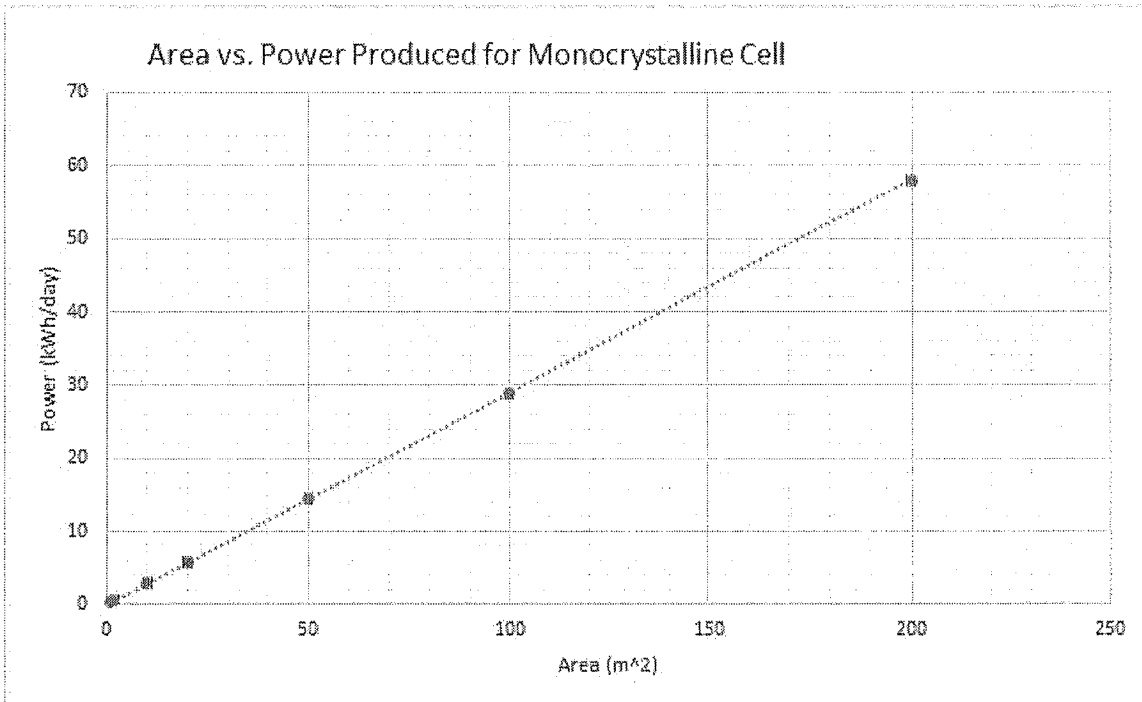
| Table 3: Monovrystalline silicon cell | |
|---|---|
| Area (m^2) | Power kWh/year |
| 1 | 104 |
| 2 | 208 |
| 10 | 1083 |
| 20 | 2075 |
| 50 | 5292 |
| 100 | 10583 |
| 200 | 21165 |

| Table 4: Monovrystalline silicon cell | |
|---|---|
| Area (m^2) | Power kWh/day |
| 1 | 0.284931507 |
| 2 | 0.569863014 |
| 10 | 2.967123288 |
| 20 | 5.684931507 |
| 50 | 14.49863014 |
| 100 | 28.99452055 |
| 200 | 57.98630137 |

Graph 1:




Interpretation: This graph shows that according to the simulation there is a direct relationship between the area of the solar cell and the amount of power produced. The gradient of the trend line is 0.138 $kWh/daym^2$ which means that for every square meter of anamorph silicon cell 0.138 kWh of power would be produced given the conditions of my garage roof. This can be modeled by the equation $P = (0.138\ kWh/daym^2)A$




Interpretation: This graph shows that according to the simulation there is a direct relationship between the area of the solar cell and the amount of power produced. The gradient of the trend line is 0.290 $kWh/m^2$ which means that for every square meter of Monocrystalline silicon cell about 0.290 kWh of power would be produced given the conditions of my garage roof. This can be modeled by the equation $P = (0.290\ kWh/daym^2)A$

*note: since data was collected from a computer simulation and the simulation does not give a level of uncertainty, it does not make sense to include a value of uncertainty or error bars for the graphs.

The equation that gives the power converted by a solar panel:

$P = \eta I A$

$\eta$ - efficiency

$P$ - total power converted by panel

$I$ - Intensity of sun's radiation per square meter

$A$ - Area of panels

Using the information gathered in data table 2 and the estimation that the average power radiated by the sun per hour per meter squared for seattle washinton per day is about 3.57kWh/day (Alternative 2013), the efficiency of one square meter of Anamorph solar cells positioned on my roof would be calculated as:

$$\eta = \frac{P}{AI}$$

$P$ = .304kWh/day

$I$ = 3.57 kWh $day^{-1}$ $m^{-2}$

$A$ = 1$m^2$

$$\eta = \frac{(.304kWh/day)}{(1m^2)(3.57kWh/daym^2)}$$

$\eta = 0.085$ or about 8.5% efficiency

Using the information gathered in data table 2: the efficiency of one square meter of Monocrystalline solar cells positioned on my roof efficiency would be calculated as:

$$\eta = \frac{P}{AI}$$

$P$ = .285 kWh/day

$I$ = 3.57 kWh day$^{-1}$ m$^{-2}$

$A$ = 1m$^2$

$$\eta = \frac{(.285kWh/day)}{(1m^2)(3.57kWh/m^2)}$$

$\eta = 0.080$ or about 8% efficiency

My family used about 42.7kWh per day last January. Using the equation derived from graph 1 the area of Anamorph solar cells needed to power our home last January can be calculated as:

$P = (0.138\ kWh/daym^2)A$

$42.7kWh/day = (0.138\ kWh/daym^2)A$

$A = 309m^2$

If we instead used monocrystalline solar cells the area needed would be calculated as:

$P = (0.290\ kWh/daym^2)A$

$42.7kWh/day = (0.290kWh/daym^2)A$

$A = 147m^2$

In July of last year my family only used about 33kWh/day of power. The area of solar panels we would need during this time of year would be calculated as:

Anamorph

$P = (0.138\ kWh/daym^2)A$

$33.0kWh/day = (0.138\ kWh/daym^2)A$

$A = 239m^2$

Monocrystalline

$P = (0.290\ kWh/daym^2)A$

$33.0kWh/day = (0.290kWh/daym^2)A$

$A = 113m^2$

## Conclusion and Evaluation

So we would have had to use 309 square meters of Anamorph Silicon cells or 147 Square meters of Monocrystalline solar cells in January and 239 square meters of Anamorph Silicon cells or 113 square meters of Monocrystalline solar cells in July. Considering my garage roof is only 38 square meters this plan is not very feasible for any season.

The efficiency calculations of 8% and 8.5% were perhaps a little low since, according to the Homer IB physics textbook present day solar cells have efficiencies of about 20%. One thing that was not taken into account is the idea that solar panels tend to have higher efficiencies in cooler climates even though the intensity of sunlight is less.

One strength of using a simulation is exact values for power produced. One weakness of this particular simulation is that it did not have a feature where you could see how power produced would vary by season. The ability to calculate power produced based on area for different times of the year would have made the calculations of area needed for certain amounts of power in January and July much more accurate.

An idea to extend and improve this experiment would be to measure myself the solar intensity at my house in order to get a value more specific to my needs. Additionally, one might consider how the values might differ for solar panels were mounted facing different directions or were equipped with tracking systems that followed the sun.

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