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The Calculus of Solar Panels

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When people talk about alternate versions of energy, solar energy is often brought up as an option. But how is it that we can convert light energy into electrical energy? The calculus that is involved in a solar panel will be discussed a little later, as first a person must understand why solar panels are made out of only certain materials.

For the most part, solar panels are made out of silicon compounds, which have been useful due to large amount of the resource available. But the reason that silicon is so useful is the natural properties of the crystal. When sunlight hits the crystal, the electrons get excited to a higher energy level and remain at that level until the energy is used. In a solar panel, the energy is taken from the excited electron and used in a chain of electrons that create a current that can be used. There are currently other materials that are also being tested that are able to have more electrons become excited by utilizing the higher part of the electromagnetic spectrum.

The calculus of the solar panel comes in when calculating the power that can be produced and the amount of power that can be provided when the sun is at a certain angle. The power is the rate with respect to time at which the electrical energy is produced. It is possible to calculate the amount of energy converted by integrating the power from time t = a to t = b. The energy comes from the potential energy in the crystals.

Electrical potential energy negative of the work done by electrostatic force, integrate from the reference position to some position r

$$\int_{r_{ref}}^{r} F ds$$

where $F = k * \frac{q_1 q_2}{d^2}$. Power is the rate of change of energy with respect to time:

$$P = \frac{dE}{dt}$$

The total energy over a time period is the integral of power with respect to time:

$$E = \int_a^b P dt$$

The amount of light energy depends on the angle that the sunlight is coming from. This intensity is proportional to the sine of the angle *A* of elevation of the sun above the horizon. And so, the total amount of energy that can be received on a day *T* must be the product of a constant that is determined through experimentation and the integral

$$\int_{t_0(T)}^{t_1(T)} \sin(A)\, dt$$

where *t* is the time of day measured in hours from noon and $t_0(T)$ and $t_1(T)$ are the sunrise and sunset on the day *T*. The equation of sin(*A*) can be expanded to take in multiple different factors that the Earth presents. The equation expands with the variables as follows:

- *A* the angle of elevation of the sun above the horizon
- *l* the latitude of a place on the earth's surface
- *α* inclination of the earth's axis (23.5° or 0.41 radians)
- *T* time of year, measured in days from the first day of summer in the northern hemisphere
- *t* time of day, measured in hours from noon

$$\sin(A) = \cos(l)\sqrt{1 - sin^2(\alpha)cos^2\left(\frac{2\pi T}{365}\right)}\cos\left(\frac{2\pi t}{24}\right) + \sin(l)\sin(\alpha)\cos\left(\frac{2\pi T}{365}\right)$$

And to take into account when sin(*A*) is negative, this only occurs when the sun has either yet to rise or after it has set, so solar intensity is zero and no energy is being produced.

It is clear from these equations and the thought that was required to take all scenarios into account that to make the expanded form of sin(*A*) that much more than just the physics of the silicon crystals was taken into account when setting up a solar panel so that it may provide the most energy possible to the customer.