Solar Power: Is It Worth the Energy?

With the end of fossil fuels now definitely in sight, we need to find a new major and long-term source of energy. One of the most promising sources of renewable energy is solar energy and it is clearly a long-term source: it will be available as long as the Sun renders the Earth is habitable. However, there are some questions to be considered: Is there enough sunlight to make capturing and converting it worthwhile? What technologies have been developed that allow us to capture this energy? Well, over the past years, scientists have been developing technologies that allow us to capture and convert this energy from the sun to provide heat and electricity. This energy is also called solar radiation. It is the heat and light you feel when you step outside on hot, clear day.

Immediately, however, there is one major problem with relying on the sun to provide our energy, especially in Britain. The amount of solar radiation we are able to capture and convert to other useful types of energy very much depends on where in the world we live. The problem is that, although every location on Earth receives sun light for all or at least part of the year, in a lot of places it is just too weak to make it economically viable to convert the energy. The differences in the strength of the sun's energy are due to the angle at which the sun's rays hit the Earth's surface. In the equatorial regions the Sun's energy is at its strongest because its rays hit the Earth at very close to 90°. They do not have very far to travel in the atmosphere so they do not diffuse and scatter as much. As you move further away from the equator, towards either of the poles, the sun's rays become more slanted, travelling further through the atmosphere and becoming more and more diffuse and scattered. The more scattered the rays become, the less energy is available so it is much less economical for far northern and southern countries to harness solar energy.

Location, however, is not the only factor that affects the amount of energy that reaches the Earth's surface. Atmospheric absorption can also affect the strength of the solar energy at any particular point; on a clear, dry day the direct radiation can be reduced by about 10% whereas on a damp, cloudy day it can be reduced so much that what energy there is, is not enough to be captured.

Despite all of this, in Britain solar energy is becoming ever more popular as an alternative energy source. The two most common ways of using this energy is by converting it into electricity for use in the home and also for heating water. In order to do this on a domestic scale you need to have a solar thermal or photovoltaic (PV), system. They are reliable (as long as there is sufficient light and heat) and pollution free but at the moment are relatively expensive.

The basic principle of generating the electricity is based on the sunlight literally knocking electrons out of the shells of the atoms in a semiconductor in the cell, usually silicon. The now free electrons are forced to flow in a current by the electric field, or fields, in the cell. Electrical contacts are placed on the top and bottom of the cell that make it possible to draw the current out for external use.

Silicon is the semiconductor that is usually used in solar cells because it has some very useful and special properties, especially in its crystalline form. Each atom of silicon has 14 electrons in the shells around the nucleus; the outer most shell containing only four out of a possible eight electrons. In order to fill their last shell, each atom forms covalent bonds with the four atoms nearest to it. It is this that forms the crystalline structure which turns out to be so important in this type of PV cell. This pure silicon, however, has a major flaw: when the radiation from the sun strikes the silicon it frees a few of the electrons from the structure. These electrons are called free carriers as they are able to wander freely through the structure but they are also able to carry an electric current. The problem is that so few are freed from the pure silicon structure that they are not very useful. Also, with only pure silicon in the cell, no electric field can be created which would render the cell useless.

The problem with the pure silicon is that the electrons are "locked away" in bonds in the crystalline structure which makes the substance a poor conductor of electricity. Because of this, the silicon in many solar cells is modified to have a very small number of phosphorous atoms and boron atoms "grown" into the structure. The phosphorous atoms have five electrons in their outer shells rather than four so when they form covalent bonds with the silicon atoms they still have one free electron held in place only by a proton in the nucleus of the respective atom. The boron atoms only have three electrons in their outer shells so they have free "holes". It takes much less energy to knock these electrons and "holes" free and, as a result, most do break free from their bonds do break free. With many more free carriers, this silicon "doped" with phosphorous and boron is a much more effective electrical conductor than pure silicon. The half "doped" with phosphorous is called N-type silicon because of the extra electrons that give it a negative charge; the other half that is "doped" with boron is called P-type silicon because of the free "holes" giving it a positive charge. Where the two types meet at the junction the some of the free electrons and "holes" form a barrier that acts as a diode and prevents the electrons crossing from the N-type side to the P-type side to join with the "holes". When we add the solar radiation to the cell, it frees more of the electrons and "holes" and if we supply an external current path, the diode will force the electrons to flow as a current along it from the N-type side to the P-type side. Along this current path, the electrons can do work for us before they return to the cell. The flow of the electrons provides a current and the electric field in the cell pushing the electron along the current path provides a voltage. The product of the current and the voltage is the desired one: electrical power.

Although sunlight contains a huge amount of energy, a solar cell is very inefficient and can only utilise a small portion of this energy. Solar radiation consists of the entire electromagnetic spectrum which means lots of different wavelengths and therefore energies. Some of the photons do not contain enough energy to form an electron-hole pair so they will simply pass straight through the cell without affecting it. Others however have too much energy so they will form an electron-hole pair but the extra energy will be lost unless there is enough to release two pairs. These two affects alone are responsible for the loss of roughly 70% of the radiation energy that passes through the cell. Unfortunately, we are not able to use a different material that needs less energy to form the electron-hole pairs than silicon without losing some of the voltage, and therefore the power.

There are energy losses within the cell as well. We are able to put a large, electric conducting, metal contact on the underside of the cell to draw the current out but on the top side we are not able to do this. If we covered the top side of the cell, the photons would not be able to penetrate the opaque surface so there would be no current to draw out. We have to put a small contact on the top surface to allow as much light to get through but this also has a problem: silicon is a semiconductor so there is a lot of internal resistance acting against the electrons within the structure. To reduce this as much as possible, the metal contact is a grid that covers the surface of the cells but still allows the light to penetrate the cell. The grid means that the electrons do not have to travel as far though the resistant silicon before they reach the less resistant current path and maximum amounts of light can still reach the cell.

Apart from the energy loss problems, there are some other issues with using solar panels. First, they are still relatively expensive and the pay-back time is long due to their inefficiency. Also, it is very difficult to place the panels where they can work to their full potential. They need as much sunlight as possible in order to produce worthwhile amounts of electricity and ideally should track the sun.

There is another, cheaper and more efficient way of utilising the sun's energy: for generating heat. The method behind it is much simpler than for generating electricity. All you need is a panel on your roof in an area that receives plenty of sunlight. The panels are usually painted matte black which allows them to absorb maximum amounts of sunlight and have pipes inside them that carry the water. The cold water is fed into the bottom of the panel and, as it heats up and gains energy, it rises to the top and is transported, through insulated pipes, to a tank which then feeds the hot water into your hot water tank in the house. The water can hold its heat for a relatively long time if the tank is sufficiently insulated so the system is very efficient and you do not usually require a boiler to heat any extra water.

There are a couple of problems however. In Britain, the time of year when people usually require the most hot water is in winter when we are not able to produce as much heat from the sun. Also, the payback time is between seven and eight years which is quite a while although it can reduce hot water bills significantly in that time.

Even though there are some problems with both the solar cell and the solar thermal system at the moment, within the next few years, new technologies will allow their efficiency to improve and the cost to decrease. This means they will become ever more popular as a replacement form of energy to fossil fuels which are becoming ever more expensive as the supplies diminish, and when the improvements have been made they are sure to become one of the world's most important sources of energy.

Acknowledgements

http://science.howstuffworks.com/solar-cell2.htm

www.wikipedia.com

"Environmental Applications of General Physics" by John I. Shonle

Geoff Batty