Electricity from the Sun

Price 30p

Introduction

The available solar energy is vast. The total fossil fuel reserves in the world represent barely 3 days of the solar energy received by the earth. Solar energy warms the earth, powers the growth of vegetation and re-cycles desalinated water from the oceans. It is being focussed by mirrors to heat boilers and generate electricity and, by heating roof panels, produce hot water in homes. In fact solar 'thermal' as it is called provides more renewable energy worldwide than wind. This note explains how *electricity* is produced from the sun.

How do solar cells work?

Small scale solar electricity is produced via solar 'cells'. Some materials such as copper are good conductors of electricity. Others such as rubber are so poor they are used as insulators. Silicon and a few similar materials lie in the middle of this range and are called 'semi-conductors'. As such they are ideal for controlling the movement of an electrical current.

In a typical solar cell a thin slice of silicon, perhaps 10 centimetres square, is infused with two different substances. These produce a surplus of electrons in one part of the silicon and a shortage in the other. Light energy falling on the cell energises the surplus electrons causing them to cross the 'junction' between the parts, producing an electric current.

Cells are grouped in a panel and linked to form an array of the capacity required. The voltage produced will usually be 12 or 48 volts. A current will flow so long as sufficient light energy falls on the cells. The amount varies pro rata to the amount of light.

The electrons move in only one direction providing what is called a 'direct current' (DC). Most electricity is generated by rotating turbines which produce a variable or 'alternating' current. Where solar power is used to supplement electricity from the national grid, 'inverters' are needed to convert the 12 or 48 volt DC output to 230 volt AC supplies. Cost usually has to include the 'inverter', wiring and meter plus the labour cost of erection. Panel maintenance costs are low but inverters have been troublesome lasting only 10-15 years.

Costs not yet attractive

Though large areas of solar panels are in use capital costs remain high. Scientists are juggling different materials, with different costs, efficiencies, longevity, and problems of ultimate disposal. (Some materials used such as gallium arsenide are particularly toxic.) The current market leader, accounting for some 90% of sales in 2004 but 78% now, is mono-crystalline silicon with up to 15% efficiency in commercial use. Previously life expectancy was 20-25 years (where 'life' is defined as the number of years an array gives a minimum of 80% of its initial output) but this is improving. The Energy Savings Trust put the cost of solar systems in the UK at between £4,500 and £8000/kW installed. A 1 kW panel would be about 7 square metres (m^2) in area. 2 kW arrays are common. With ample space, eg large factory roofs, low efficiences can be accepted. An amorphous silicon system would cost less but cover 16 m^2/kW.

The main cost of the panel is the silicon which needs to be 99.9% pure. This has been sourced from rejected computer chips but the supply is obviously limited. Recognising that purpose made chips are expensive and costs unlikely to come down, Shell abandoned silicon in 2006 and now make cells by spraying thin layers of a copper indium deselenide (CIS) solution onto glass. This is cheaper and less complicated and there is less risk of fracture, though efficiencies are not yet as high.

240 acre solar 'farm' Cimarron, New Mexico

Cadmium telluride thin films are also being used.

The energy from the sun varies with time and place. In the UK it is 10 times greater in summer than winter. On the south coast a 1 kW array might produce as much as 1200 units of electricity (kWh) in a year though 900 is more likely. 700 is nearer the UK average. This, at 10p/unit, would bring in only £70/year - a return of barely 1%/year, not enough to recover the capital cost. In California the same array would give 2200 units, tripling the rate of return but still not covering the capital cost.

The sun does not need to shine directly on the panels. Where it does, output will be more if the panels move with the sun but this is not practical for small household

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installations and, in the UK where most light is diffused by cloud, not worthwhile for large ones. Here panels need to be south facing and inclined at 42º, or 10º less than latitude. Happily most UK roofs are near this angle

Statistics for solar panels tend to vary. In 2000 about 200 MW of panels were being produced globally with about 800 MW installed whereas in 2009 some 9,000 MW were added raising the total to over 22,000 MW, an astonishing rate of growth. Germany had almost half of these with Italy and Spain following. They are mostly small scale installations on houses and commercial buildings of a few kilowatts but some very large 'farms' are beginning to be built. There is a 15 MW 'farm' at the US Nellis air force base in Nevada which provides 25% of demand, a 20 MW farm at DeSoto, Florida, a 30 MW farm under construction at Cimarron in New Mexico and plans for 6 farms in California which, if constructed, would have a total capacity of 3000 MW. Somewhat smaller planning approval has been obtained for a £10-12M, 5 MW, farm at Lyhandrock in Cornwall. The Cimarron farm will cover 1 square kilometre, contain 500,000 solar panels and cost £170 M, at least double the cost of offshore wind.

Indeed, so high is the cost it is not clear the industry will go this way for very large installations. The alternative is to forget solar panels and instead use mirrors to reflect the sun's energy and either concentrate it on a boiler at the top of a tower or a pipeline to raise steam just as any other thermal power station does. The efficiency would be at least twice as high as with solar panels. There is one tower near Seville and a pipeline plant at Alvarado, both in Spain and a lot of interest in North Africa, Australia and elsewhere in this option.

But, this is far from the end of the story

Although solar electricity is also expensive at the small scale, adding a battery provides a 'stand alone' installation. This saves the cost of connection to the grid which can be high, even if one exists, and requires no need for an inverter. Street signs, remote communications stations, navigation buoys, even pond fountains can all 'stand alone' and, in developing countries (often with no grid anyway), the potential is great. Water pumping, refrigeration, lighting, daytime power - all can be solar driven. Maintenance needs are low so they can be more reliable than diesel generation.

In the UK another market is for panels which serve a dual use. They can double as roof tiles or be used as cladding to buildings (eg multi-storey offices). The cladding needs to be separated from the building so that the heat can dissipate, and the cost exceeds bricks or concrete but is cheaper than marble and other high quality surfacings. Solar panels can shelter walkways and be tinted in various colours, though efficiency drops.

An intriguing use

Two intriguing uses of solar energy are for refrigeration and air conditioning (the 2022 Qatar football stadiums may be cooled this way) because *output* will rise with the sun and so *match* demand. In 1997 scientists at Southampton University put 30 m^2 of efficient panels on the roof of a Sainsbury's refrigeration truck. They added batteries, removed one of the truck's two engines and equalled a conventional unit in performance. A canal boat was using solar panels to keep vaccines cool as they were delivered round the country.

Main problems to be overcome

Problems remain. Dust is one though this country has ample rain and a yearly clean is enough. Some of the most attractive materials are toxic and installation companies are worried about their liability if the panels break or are disposed improperly at their life's end. Developing countries could end up with piles of worn out lead acid batteries. Manufacture has similar toxicity problems to those in the electronics industries. Attaching solar panels to the grid poses safety problems. At present electricians know they will be safe if they isolate a supply from the grid, but if electricity can come 'up' the line from solar panels as well as 'down' from the grid they won't have that guarantee. Current regulations require inverters to shut down *immediately* the grid supply fails. 'Two-way' meters (so householders get the right rebate for exports to the grid) add expense. Lastly the panels actually consume substantial energy in their manufacture, several years in some cases.

The future

Looking at the limits of other renewable alternatives, more electricity *has* to be generated from the sun. Germany has supported a huge 'roof top' programme with an average of just over 3kW/roof and generous feed in tariffs. Japan did the same and subsequently Spain followed. Each country hoped to stimulate the market and bring costs down to economic levels but this hasn't happened. Germany cut rates by 15% from April 2010 and Spain and Japan are losing enthusiasm.

In the UK most installations are 'stand alone'. In Plymouth 330 bus shelters use solar arrays for lighting and this use is spreading. Electricity is stored in concealed lead-calcium batteries and used in efficient lighting after sunset. Combined wind turbine/solar panel powered traffic signs are also increasingly common. Rather late in the day the coalition has gone down the 'feed in' tariff route and will pay 36.5p/kWh for all electricity generated with 5p more for any surplus exported to the grid.

It is not clear this is a sensible. The economics of solar energy will never be as good in the UK as in countries further south and, if the Germans can not make PV economic, the UK will also struggle. There is some merit trying solar panels along the south coast but a much better case for developing stand alone items, dual purpose systems and others designed to power air conditioning units. Even better would be to find an economic way to store electricity. Cheap storage would also benefit wind and tidal energy, which we have in abundance. Unhappily UK solar energy tends to be available only when it is least needed.