The Oil Drum: Europe
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Concentrating Solar Power

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This is a guest article by Gerry Wolff, coordinator of TREC-UK. 'TREC' stands for the Trans-Mediterranean Renewable Energy Cooperation, their website is at www.trecers.net. These webisites are a fantastic source of informaion on concentrating solar power.

Dish/engine systems from Solar Systems at Umuwa, South Australia

Introduction

It is said that, in 212 BC, Archimedes used polished bronze shields to focus sunlight, trying to set fire to wooden ships from the Roman Empire that were besieging Syracuse. Although we don't know whether he succeeded, the Greek navy recreated the experiment in 1973 and managed to set fire to a wooden boat at a distance of 50 metres. In the 16th century, Leonardo da Vinci proposed the use of concave mirrors to concentrate sunlight to heat water.

It was not until the late 19th century and early 20th century that the idea of capturing solar energy with mirrors was tried on an industrial scale in California, Egypt and other places with lots of direct sunshine. But the era of cheap fossil fuels snuffed out these early developments and it was the mid 1980s before serious attempts were made again to apply the technique of 'concentrating solar power' (CSP).

The basic idea is to arrange mirrors so that they concentrate sunlight into a relatively small area and then use the resulting heat to raise steam to drive turbines and generators, just like a conventional power station. Direct sunlight is needed and CSP works best when sunshine is plentiful, as it is in hot deserts. In those kinds of conditions, CSP is currently the most costeffective way of capturing solar energy but this might change in the future with further developments in photovoltaics (PV).

A nice feature of CSP is that it is possible to store solar heat in melted salts (eg nitrates of sodium or potassium) so that electricity generation may continue at night or on cloudy days. This is currently a lot cheaper than flow batteries or other technologies for bulk storage of electricity. Because CSP plants are so similar to conventional power stations, it is also possible to use gas as a stop-gap source of heat when there is not enough sun. With heat storage and hybridisation with gas-firing, CSP plants can provide base load, intermediate load and peaking power according to need.

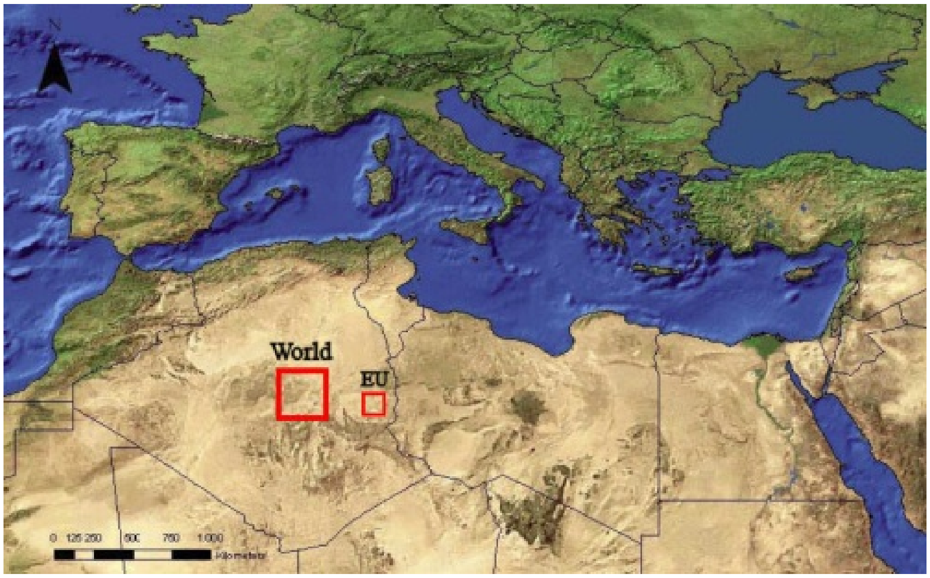
There are several variations on the scheme that I have outlined, including systems that use heat to drive a Stirling engine and generator, and hybrid schemes that use mirrors in conjunction with PV.

Solar Two tower and heliostats in Daggett (Barstow), California.

New developments and potential

Currently, there are CSP plants in the Mojave desert producing 354 MWe (peak), and there are smallish installations elsewhere in the world. But concerns about CO_2 emissions and future energy supplies have led to a recent surge of interest in CSP, with new plants now being planned or built around the world.

The statistics are quite startling. Every year, each square kilometre of hot desert receives solar energy equivalent to 1.5 million barrels of oil. Multiplying by the area of deserts worldwide, this is several hundred times the entire current energy consumption of the world. It has been calculated that, if it was covered with CSP plants, an area of hot desert of about 254 km x 254 km—less than 1% of the total area of such deserts - would produce as much electricity as is currently consumed by the whole world. An area measuring 110 km x 110 km, a small fraction of the area of desert in North Africa and the Middle East, would produce the same amount of electricity as the European Union consumed in 2004. In a report published in January this year, the American Solar Energy Society says that "...analysts evaluated the solar resource in the Southwest [of the US] and ... found that CSP could provide nearly 7,000 GW of capacity, *or about seven times the current total US electric capacity*." (emphasis added).



What has this got to do with the UK?

Of course, the UK is not over-endowed with hot deserts and it is natural to assume that CSP is not relevant to our needs. But for reasons that I will describe, CSP could become a major source of carbon-free energy for the UK and many other countries that do not themselves have deserts.

One possibility, which is not entirely frivolous, is to take Mahomet to the mountain: relocate energy-intensive industries so that they can make direct use of thermal or electrical energy from CSP plants in desert areas. For example, the heat and electricity that is needed to convert bauxite into aluminium could be provided by CSP plants in the Australian desert, close to where the bauxite is mined. Naturally, this would not assist the production of aluminium in the UK, but in the highly inter-dependent global village that we live in now, this kind of solution to energy-supply problems could be a major benefit.

Another possibility is to transport solar energy over long distances using hydrogen as an energy vector. In principle, the hydrogen could be derived from water by the direct application of solar heat and there have been some experiments along these lines. But until such time as this can be done efficiently on a large scale, hydrogen may be generated by the electrolysis of water using solar electricity.

Hydrogen that is produced in this way could be used as fuel for trains, road vehicles or even planes. But if hydrogen that is derived from CSP is merely a means of recreating electricity in the UK or other distant location, then it quickly begins to lose its shine. It has been calculated that about 75% or more of the original electrical energy would be lost in conversions and processing that would be required between CSP electricity at its source and electricity at a distance, created by the combustion of hydrogen.

If electricity is what is needed at the destination, then in almost all circumstances it is very much more efficient to transmit solar electricity directly using high-voltage transmission lines. HVAC works well over relatively short distances but for longer distances, HVDC is the preferred option. With transmission losses at about 3% per 1000 km, electricity may for example be transmitted from North Africa to the UK with less than 10% loss of power.

150 MW of parabolic trough CSP plant at Kramer Junction, California.

The DESERTEC concept

The ideas that I have sketched are part of the 'DESERTEC' concept, a set of proposals for future electricity supplies in Europe, the Middle East and North Africa (EUMENA) that has been developed by the 'TREC' international network of scientists and engineers. The proposals are described in considerable detail in the 'MED-CSP' and 'TRANS-CSP' reports prepared by a team of researchers at the German Aerospace Center. Copies of these reports may be downloaded via links from www.trec-uk.org.uk/reports.htm.

The second of those reports shows how, in the period up to 2050, Europe could meet all its needs for electricity, make deep cuts in CO_2 emissions from electricity generation, and phase out nuclear power at the same time. Compared with the situation now, there would be an increase in the *diversity* of sources of energy and there would be an overall *reduction* in imported sources of energy. Those two things together would mean an overall increase in the resilience and security of electricity supplies. CSP would be just one element in the mix - up to 15% of the total - and would be an exception to the rule of reduced imports.

An important part of the DESERTEC concept is the creation of a large-scale HVDC transmission grid, spanning the whole of EUMENA, and designed to work in conjunction with existing HVAC grids. This proposal chimes well with an independent proposal by Airtricity to create a Europe-wide HVDC grid. One advantage of this kind of grid is that it provides an answer to the often-voiced objection to wind power—that "the wind does not blow all the time". This is true in any one relatively small area but it is almost never true across a large area like Europe. Another advantage of large-scale HVDC grids is that surplus electricity in any one area - more than the local people can use - may be moved to other areas where it is needed, thus reducing the wastage of energy that may otherwise occur.

An interesting aspect of the Airtricity proposal is that all the power cables would be laid under the sea! Modern designs of HVDC cable make this a realistic option now. One advantage is that it would largely eliminate any problems of visual intrusion. And it would greatly simplify the processes of planning and construction.

One of the most fascinating aspects of the DESERTEC concept are various spin-off benefits, especially for local people in host countries. For example, waste heat from CSP plants may be used for desalination of sea water - a very useful bonus in arid regions. The shaded areas under CSP mirrors are protected from the full glare of the tropical sun and may be used for many purposes, including horticulture using desalinated sea water. Throughout EUMENA, there would jobs and earnings in a large new industry. More generally, the development of a win-win collaboration amongst countries of EUMENA, with substantial benefits for all, would be a good way to promote good relations and mutual understandings across the region - a positive alternative to the confrontational policies of recent years.

Dish/engine systems from Stirling Energy Systems at the Sandia National Laboratories in Albuquerque, New Mexico.

Costs

The cost of collecting solar thermal energy equivalent to one barrel of oil is about US$50 right now (already less than the current world price of oil) and is likely to come down to around US$20 in the future. The MED-CSP report, published in 2005, suggests that CSP will need public support for a time (like other renewable forms of energy) but that, with economies of scale and refinements in the technology, the cost of CSP electricity is then likely to tumble relative to more traditional sources of electricity. The TRANS-CSP report calculates that CSP is likely to become one of the cheapest sources of electricity in Europe, *including the cost of transmission*.

A report in Business Week (2006-02-14) quotes the CEO of Solel as saying “Our [CSP] technology is already competitive with electricity produced at natural-gas power plants in California”. Similar claims are being made by others in the industry. Speaking about CSP at the Solar Power 2006 conference in California, the US venture capitalist Vinod Khosla said “...we are poised for breakaway growth - for explosive growth - not because we are cleaner [than coal-fired electricity] but because we are cheaper. We happen to be cleaner incidentally.”

Parabolic trough mirrors with maintenance workers at Kramer Junction, California.

Security of supply

Although few people express any worries about the fact that the UK produces only about 60% of the food we eat, a surprisingly large number of people seem to think that it would be quite unacceptably risky to import some of our electricity from North Africa and the Middle East. For several reasons, I believe that any possible risk is more apparent than real.

The number of countries with hot deserts is quite large so we would not need to be overly-dependent on just a few sources of CSP electricity, as we are with some other sources of energy. Given the substantial benefits that CSP would provide for host countries, there is little incentive to disrupt their operation. The transmission grid can be designed to accommodate damage in very much the same way that the internet was designed to be resilient in the face of military attack: rather than rely on a few large transmission lines, electricity may be transmitted over a network of smaller transmission lines; and submarine cables, as proposed by Airtricity, would be relatively safe from attack. CSP plants would be difficult to damage by any kind of attack and they would be easy to repair.

Conclusion

The DESERTEC scenario, which has been developed with considerable professionalism and care, shows that concentrating solar power can be an important source of carbon-free electricity, not just for countries in the sun belt but for many other countries as well—including the UK. Additional potential benefits include the not-insignificant prize of improved relations amongst different groups of people.

All the relevant technologies are available now. With the right political impetus, the necessary infrastructure can be put in place quite soon.

Close up view of parabolic trough and heat collector.

Technical information is available in the two reports prepared by a team of researchers at the German Aerospace Center:

Trans-Mediterranean Interconnection for Concentrating Solar Power (TRANS-CSP, 2006, PDF, 6.1 MB).
Concentrating Solar Power for the Mediterranean Region (MED-CSP, 2005, PDF, 11.9 MB).

Copies of these reports may be downloaded via links from www.trec-uk.org.uk/reports.htm.

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