Clean power from deserts and adaptation to climate change[1]

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Every year, each square kilometre of 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.

Given current concerns about energy supplies and the need to cut emissions of CO_2, these rather startling statistics seem to be a cause for optimism. But, you may very reasonably ask: Can we tap into this enormous source of energy at a reasonable cost? Can we get it to where people are living? And, if those things are possible, what other snags or problems might there be?

The purpose of this article is to describe some answers to those questions and suggest that one's initial sense of optimism about this 'Desertec' scenario may be something more than just a mirage. It will also describe how tapping in to the power of deserts can help people adapt to changes in the climate that are already in the pipeline.

Clean power technologies

At present, the key technology for generating solar electricity in desert regions appears to be 'concentrating solar power' (CSP). This is not some futuristic possibility like fusion nuclear power. It is the remarkably simple idea of using mirrors to concentrate direct sunlight to create heat and then using the heat to raise steam to drive turbines and generators, just like a conventional power station. However, in some variations, the heat is used to drive a Stirling engine that drives a generator.

A useful feature of CSP is that it is possible to store solar heat in melted salts (such as nitrates of sodium or potassium, or a mixture of the two) so that electricity generation may continue through the night or on cloudy days. It is also possible to provide backup sources of heat such as gas or biofuels. These things enable CSP to deliver power on demand, day and night, which is very useful for power engineers in balancing supplies of electricity with constantly varying demands.

CSP is very different from the better-known photovoltaic panels (PV) and, with current prices for PV, it can deliver electricity more cheaply in situations where lots of direct sunlight is available. However, PV may become cheaper in the future and methods for storing PV electricity are likely to improve – so the balance of advantage may change. Just to confuse matters, the technique of concentrating sunlight with mirrors is sometimes used in conjunction with PV, to minimize the amount of PV

1. This article is an updated version of "The potential of power from deserts" by Gerry Wolff published in the *Newsletter of Scientists for Global Responsibility*, Summer 2007, Issue 34, pp 5-7. A PDF copy of that article may be downloaded from http://www.desertec-uk.org.uk/articles/SGRNL34_GWarticle.pdf that is required. And we should not forget that wind power is also an attractive option in desert regions.

The relative merits of different technologies and different versions of CSP will, no doubt, be the subject of study and debate for years to come. The key point here is that CSP technology works, it is relatively mature and has been generating electricity successfully in California since the mid 1980s. Currently, about 100,000 Californian homes are powered by CSP plants, new plants have come on stream in Arizona and Spain, and others are being planned or built in several other parts of the world.

Getting the energy to where it is needed

Given that, with a few exceptions, desert regions are not places where many people choose to live, it is natural to ask how all this plentiful supply of energy is to be used. One possibility is to move energy-intensive industries such as aluminium smelting to desert areas. But even if all such industries were relocated, there would still be a need for the electricity to be available to towns and cities elsewhere.

The high-voltage alternating-current (HVAC) transmission lines that we are all familiar with work well over relatively short distances but they become increasingly inefficient as distances increase. Fortunately, it is possible to transmit electricity efficiently over very long distances using high-voltage direct-current (HVDC) transmission lines, a technology that has been in use for over 50 years. With transmission losses of about 3 per cent per 1,000 kilometres, plus AC/DC conversion losses of up to 2 per cent (taking both ends together), it would for example be possible to transmit solar electricity the 2,000 kilometres from North Africa to the UK with less than 10 per cent loss of power.

Apart from long-distance transmission of solar power, there are other good reasons to build such a large-scale 'supergrid'. For example, security of supplies would be

The PS10 power tower CSP plant (foreground) and the PS20, Sanlucar la Mayor, near Seville, Spain.

increased because a shortfall in any area can normally be met from one or more other areas. Conversely, if there is a surplus of wind power in one area, it is very useful to be able to transmit that electricity to places where there is a shortage. Without that facility, the surplus power is simply wasted. And although wind power may be quite variable in any one location, it is much less variable across a large region such as Europe, the Middle East and North Africa (EUMENA). Large-scale grids are also needed to take advantage of large-scale but remote sources of renewable electricity such as offshore wind farms, wave farms, tidal lagoons, tidal stream generators – and CSP.

In connection with that last point, it is important to stress that the Desertec vision includes the use of a wide variety of renewable sources of power across the whole of EUMENA, with 'desert' electricity providing no more than about 15 per cent of European electricity supplies.

Costs
At present, estimates for the cost of electricity from CSP in desert regions range from about 10 US cents per kWh to about 20 US cents per kWh[2]. As with PV, these prices are higher than the widely-quoted 'headline' figures for the cost of electricity from fossil fuels or nuclear generators, and they are higher than costs for wind power.

However, before we conclude that wind power is the electricity-generating technology of choice for desert regions or that we should continue with coal-fired and nuclear electricity, it is important to recognize that energy markets are highly distorted and that widely-quoted figures for the cost of coal-fired and nuclear electricity are highly misleading. It is also important to recognize that, via economies of scale and refinements in technologies, the cost of electricity from CSP and PV are falling, while the cost of electricity from coal-fired and nuclear plants is on an upward trend.

Sun-tracking parabolic dish reflectors, each one with a Stirling engine and electricity generator at its focal point.

2. See http://www.desertec-uk.org.uk/csp/costs.htm.

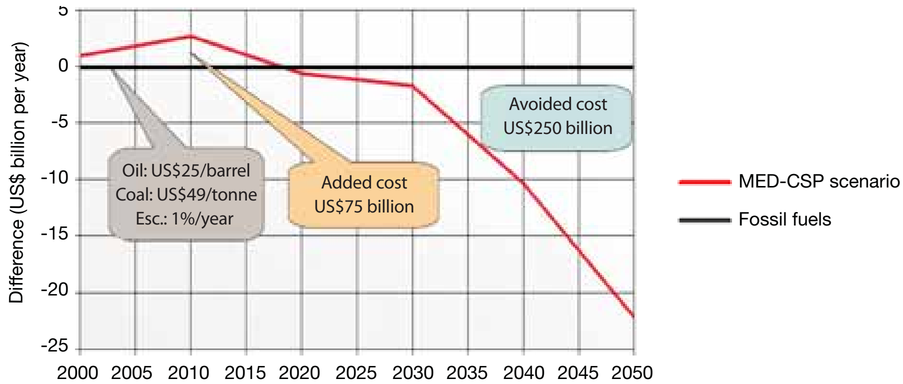

Figure 1 Cost difference between the MED-CSP scenario and a business-as-usual policy scenario. After about 2017, the cost of CSP electricity is likely to tumble compared with the cost of electricity from fossil fuels, assuming a 1% annual rise in the costs of fossil fuels (a predicted rate of increase that is smaller than the rate at which those costs have actually been rising). *Source: DLR (2005).*

The first source of distortions in energy markets is subsidies for fossil fuels and subsidies for nuclear power. A report from the New Economics Foundation found that, in 2004, worldwide subsidies for fossil fuels were about US$235 billion a year[3], and it appears that little has changed since then. The Nuclear Subsidies report from the Energy Fair group[4] shows that nuclear power benefits from seven main types of subsidy, the most notable of which are that the operators of nuclear plants are paying much less than the full cost of insuring against a Chernobyl-style accident or worse, and they are paying much less than the full cost of disposing of nuclear waste or decommissioning nuclear plants. The high cost of nuclear power is documented in several other sources[5].

The other main distortion in energy markets is that, to a large extent, the atmosphere is still being treated as a free dumping ground for CO_2. This applies mainly to coal-fired electricity but the nuclear cycle is far from being zero-carbon. An effective, worldwide system of rationing for fossil carbon, such as Kyoto2[6], would raise the price of CO_2 emissions substantially and would transform the economics of electricity generation.

The cost of CSP will certainly fall with economies of scale and refinements in the technologies. Companies such as eSolar are rationalizing designs to facilitate mass production of the equipment and to facilitate rapid installation using a minimum of skilled labour, somewhat in the manner of an IKEA flat pack. The DLR (2006) report anticipates that CSP in the Middle East and North Africa will become one of the cheapest sources of electricity in Europe, including the cost of transmission (which is about 20 per cent of delivered costs).

As mentioned earlier, the cost of PV is also falling and could become an attractive alternative to CSP, although it lacks CSP's ability to deliver power on demand via the storage of heat and the use of backup sources of heat. And wind power will undoubtedly have a significant role to play in the generation of electricity in desert regions.

Figure 1 (from DLR (2005)) shows how, up to about 2017, CSP is likely to need subsidies if it is to compete with electricity from the burning of fossil fuels (unless the earlier-mentioned distortions in energy markets have been corrected). After that, CSP is likely to become increasingly competitive with electricity from fossil fuels.

3. See, for example, "Fossil fuel subsidies 'must end'", BBC News, http://news.bbc.co.uk/1/hi/sci/tech/3818995.stm. See also "Mirage and oasis: energy choices in an age of global warming" (New Economics Foundation, June 2005, http://www.mng.org.uk/gh/scenarios/nef_energy_june_2005.pdf).

4. Which may be downloaded from http://www.mng.org.uk/nsubsidies.pdf.

5. See http://www.mng.org.uk/gh/nn.htm#subsidies

6. See http://www.kyoto2.org/.

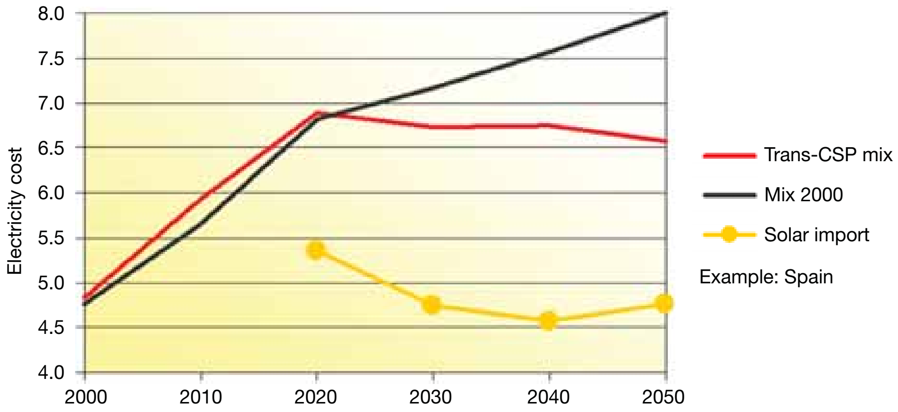

Figure 2 TRANS-CSP: Investment for least cost electricity. In the scenario described in DLR (2006), it is envisaged that, after about 2020, imports of relatively cheap solar power into Europe from North Africa and the Middle East will help to hold down the cost of electricity in Europe compared with what it would be in a business-as-usual scenario.

Source: DLR (2006).

Figure 2 shows how the import of relatively cheap solar power into Europe is likely to hold down the price of electricity in Europe compared with what it would be under a business-as-usual scenario.

Figure 3 (from DLR (2006)) shows costs and other statistics for the scenario up to 2050 developed by German Aerospace Centre. Of course, €350 billion for CSP plants and €45 billion for the HVDC transmission lines are very large sums of money. But electricity-generating equipment of all kinds wears out, so in the 40 years up to 2050 and across about 40 countries in EUMENA, similar sums would have to be spent anyway in replacing old equipment with new, even if we stayed with conventional generating technologies. Likewise, the cost of the HVDC transmission lines would be shared amongst many countries and spread over several years. Even if, as seems likely, richer countries paid most of the cost, the average annual expenditure for each of those countries – about €150 million or less – is very modest compared with other things that governments spend money on.

Making it all happen

Confidence is such that two consortia of companies have now been set up to realize the Desertec vision: the Desertec Industrial Initiative[7], aiming to build solar plants and wind farms in North Africa and the Middle East, and to develop the supergrid to

Figure 3 Total EU-MENA HVDC interconnection, 2020-2050 (for all countries analysed in TRANS-CSP). Costs and other statistics for the scenario up to 2050 developed by the German Aerospace Centre.

Source: DRL (2006), Table 2-11.

Year		**2020**	**2030**	**2040**	**2050**
Capacity GW		2 x 5	8 x 5	14 x 5	20 x 5
Transfer TWh/yr		60	230	470	700
Capacity factor		0.60	0.67	0.75	0.80
Turnover billion €/yr		3.8	12.5	24	35
Land area	CSP	15 x 15	30 x 30	40 x 40	50 x 50
km x km	HVDC	3,100 x 0.1	3,600 x 0.4	3,600 x 0.7	3,600 x 1.0
Investment	CSP	42	134	245	350
billion €	HVDC	5	16	31	45
Electricity cost	CSP	0.050	0.045	0.040	0.040
€/kWh	HDVC	0.014	0.010	0.010	0.010

7. See http://www.dii-eumena.com/

take the power to where it is needed, and the Transgreen consortium[8] focusing mainly on the development of transmission links across and around the Mediterranean sea.

There is an obvious synergy between these initiatives and other developments aiming to develop a supergrid of submarine HVDC transmission links connecting up offshore wind farms in the North Sea and elsewhere, and facilitating the transmission of electricity amongst countries in Europe[9]. Where transmission across land is needed, unsightly overhead transmission lines may be avoided because it is relatively inexpensive to lay HVDC cables under the ground.

Worldwide potential

Although the focus of the Desertec initiative has, so far, been on the EUMENA region, it is clear that the worldwide potential is colossal. It has been calculated that, using CSP, less than 1 per cent of the world's deserts could generate as much electricity as the world is using now (see Figure 4) and that less than 5 per cent of the world's deserts could generate electricity equivalent to the world's total energy consumption. Using low-loss HVDC transmission lines, it is feasible and economic to transmit electricity for 3,000 kilometres or more. And it has been calculated that 90 per cent of the world's population lives within 2,700 kilometres of a desert.

Figure 5 (overleaf) shows the areas of the world where CSP may be used and the red arrow shows roughly how far it is feasible and economic to transmit the electricity. There is great potential on every continent, including areas that do not themselves have a lot of sunshine.

Adaptation

While the Desertec concept clearly has an important role to play in fighting climate change by helping to decarbonize the world's economies, it can also help people to adapt to changes in the climate that are already in train and cannot easily be stopped even if emissions of greenhouse gases were to cease tomorrow. Those changes are

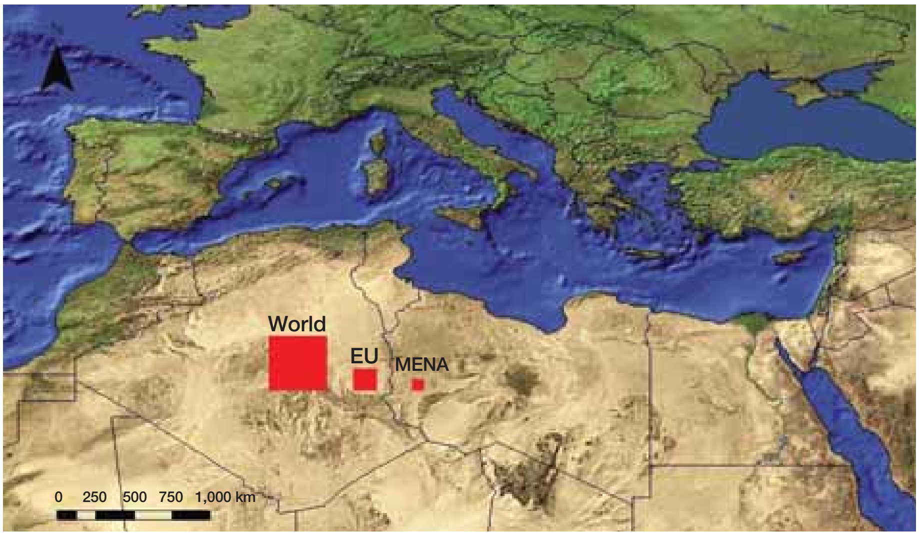

Figure 4 The red squares illustrate the size of CSP-covered area required to match the current electricity use of the world, the EU and the Middle East and North Africa, though of course not all CSP plants would be constructed together in one area.

8. See http://www.transgreen.eu/topic/index.html.

9. See, for example, http://www.friendsofthesupergrid.eu/

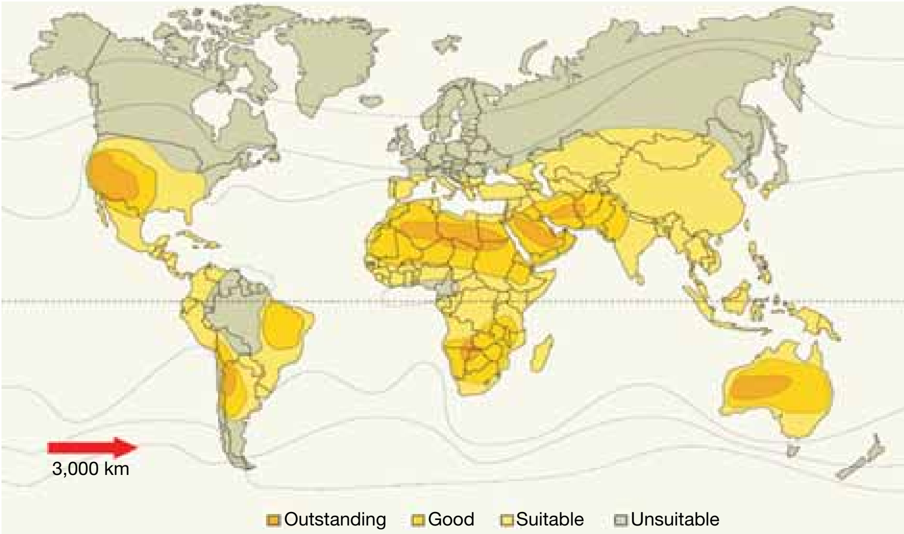

Figure 5 Potential for CSP around the world. The length of the red arrow is the approximate limit for HVDC transmission of electricity.
Source: Solar Millennium AG.

likely to include increases in global temperatures, increases in extreme weather events (heat waves, droughts, floods and hurricanes), and rises in sea level. Possible consequences include increased pressure on supplies of food and water, losses of usable land, reductions in biodiversity, and the spread of diseases into new areas.

Some of the potential of the Desertec concept to help people adapt to changes in the climate is outlined in the following subsections.

Energy

Energy is fundamental in almost every area of human activity: agriculture, transport, housing, communications, education, health care and more. And those activities are fundamental in enabling people to survive and prosper in the world as it is, and how it may be in the future. Thus plentiful and inexpensive supplies of clean electricity from desert regions are likely to be very useful in helping people to cope with changes to the climate now and in the future.

Most of the benefits will be general – assisting normal activities. But there are likely to be more specific benefits such as, for example, making it feasible and affordable for people to use air conditioning to maintain comfortable living conditions in the face of heat waves, or helping to relieve shortages of water by pumping it from where it is available to where it is needed.

Fresh water

One of the most interesting aspects of CSP is that waste heat from steam turbines (used in the production of electricity) may be used to desalinate sea water. CSP plants, like other thermal power plant, need to be cooled. If the cooling is provided by sea water, that raises the temperature of the sea water so that, if a partial vacuum is applied, water vapour may be drawn off and then condensed to create a supply of fresh water. It is also possible to use solar and wind power to drive other kinds of desalination plant.

This is obviously attractive in the kinds of arid regions where CSP plants work best. And with the likelihood of increasing pressure on water supplies in the future, the importance of solar powered desalination is likely to increase.

Shade and cooling

Another interesting side-effect of CSP is that the areas under the mirrors of a solar plant are protected from the harshness of direct tropical sunlight. These shaded areas can have a useful role to play in helping to keep things cool – such as living space, stables for animals, car parks and so on.

It is, for example, possible to mount small-scale CSP plants on the roofs of buildings or to make them an integral part of the roofs of buildings. There is a direct cooling effect via shading but additional cooling may be obtained by using the waste heat from the CSP plants to drive air conditioners – and that additional cooling is greatest when it is most needed during the heat of the day. And, of course, the CSP plants will be providing electricity for use in the building or elsewhere.

With rising global temperatures, these kinds of benefits are likely to become increasingly valuable.

Horticulture, food and land

Although the areas under solar collectors are in shadow, they should still receive quite a lot of light, quite sufficient for growing plants and without the damaging effect of direct tropical sunlight. Thus land that would otherwise be useless for any kind of cultivation could become productive. An obvious problem is that plants need water and, normally, that is not plentiful in sunny deserts. But desalination of sea water may provide the fresh water that would be needed for 'CSP horticulture'.

Since changes in the climate in the future are likely to increase pressure on food supplies and, via desertification and rises in sea level, on the availability of usable land, the kinds of development just sketched could be valuable in providing new supplies of food and of land that can be put to productive use.

Economic development

In addition to the benefits described in the preceding subsections, the technologies for capturing solar and wind power in desert regions, and transmission technologies, have the potential to become large new industries in the world with many benefits in terms of jobs and earnings, both in the construction, operation and maintenance of the equipment and via the sale of electricity into domestic and export markets. Much of the benefit will go to the countries that have the sunshine, helping to raise living standards where, in some cases, people are relatively poor.

Population

Although people all around the world are having smaller families[10], the fact that many people are of breeding age or younger means that the world's population is likely to continue growing for some time yet. This will add to the already-severe pressure on the world's resources, making it harder for people to adapt to changes in the climate that are already in train.

10. See, for example, Common Wealth: Economics for a Crowded Planet, Jefferey Sachs, Allen Lane, 2008, ISBN-13: 978-0-713-99919-8.

A close-up view of a parabolic trough solar mirror with a pipe at its focus containing heat-collecting fluid.

Since raising living standards can help to accelerate the trend to smaller families, and since, as described above, Desertec can help to raise living standards in areas where people are relatively poor, it can help to stabilize the world's population earlier than might otherwise be the case – thus helping adaptation to changes in the climate.

Improved relations between different groups of people

By alleviating shortages of energy, water, food and land, solar and wind technologies in desert regions can reduce the risk of conflict over those resources. And the development of a Desertec collaboration amongst the countries of EUMENA is a positive way of building good relations amongst different groups of people, with potential advantages over the more aggressive policies that have been pursued in recent years. These benefits will, indirectly, help adaptation to climate change.

Possible problems

It is rare for any technology to be totally positive in its effects, without any offsetting disadvantages. That said, I believe that there are good answers to most of the queries or doubts that may be raised about CSP and the Desertec scenario.

Security of supply

If Europe, for example, were to derive a large proportion of its energy from desert regions, people would naturally wonder whether supplies might be suddenly cut off by the action of terrorists or unfriendly foreign governments.

In the scenario up to 2050 described in the TRANS-CSP report, there would be an overall reduction in imports of energy, an increase in the diversity of sources of energy, and a corresponding increase in the resilience and security of energy supplies. Imports of solar electricity would be an exception to the rule of reduced imports and would, in any case, be not more than 15 per cent of European electricity supplies. Since, to avoid breaks in supply, power engineers normally aim to provide about 25 per cent more capacity than peak demand, supplies of electricity in Europe would be secure even in the unlikely event that all imports from desert regions were suddenly cut off.

Compared with sources of supply for oil and gas, there is a relatively large number of places that have sunny deserts. So in principle no country need be overly dependent on any one source of desert electricity. HVDC transmission grids can be designed to be resilient in the face of attack, in much the same way that the internet was designed to carry on working even if part of it is damaged. Transmission cables can be buried underground or laid under the sea where they would be relatively safe from terrorist attack.

Isn't this just another smash and grab by rich countries upon the poor?
One may wonder whether the Desertec project might become another case where rich countries take what they need from poorer countries leaving little for local people, except pollution.

There are reasons to think otherwise because several of the benefits are purely local and cannot easily be exported or expropriated. These include local jobs and earnings, local availability of inexpensive pollution-free electricity, desalination of sea water, and the creation of shaded areas with the kinds of uses outlined above. There is far more sunlight available than anyone can use so there is no loss to local people if some of that energy is exported.

The ecology of deserts
From at least as far back as Walt Disney's *The Living Desert*, wildlife films have made us aware that sunny deserts have their own vibrant ecology. If the world's deserts were all to be covered with CSP plants, there would indeed be cause for concern about the animals and plants that live there. But less than 1 per cent of the world's deserts would meet current world demands for electricity and, even in pessimistic scenarios, it seems unlikely that more than 5 per cent would be needed in the future. It should be possible for solar plants and wildlife to co-exist.

Water supplies
The pioneering CSP plants that have been operating in the Mojave desert in California since the mid 1980s use quite a lot of water, mainly for cooling of the output of the steam generators (something that is also needed in coal-fired and nuclear generating plants) and also for washing the mirrors. This has, quite naturally, led to concerns about pressure on water supplies, especially since CSP works best in desert regions where water is normally scarce.

It turns out that, where necessary, CSP plants can be run using little or no water. Cooling by air (called 'dry cooling') is a well-established technology although there is a small loss of efficiency. And mirrors can be cleaned using little or no water, with brushes, with compressed air, and with the aid of surface treatments that help mirrors to shed dirt or debris that may fall on them.

Conclusions
There is no doubt that planet Earth's ability to support the human tribe is being put at risk by a combination of inappropriate technologies, huge and increasing material demands, and the sheer weight of human numbers. Clean power from deserts is not a panacea but it can be a useful plank in the new ways of living that will be needed if we are to survive and prosper in the future.

Further information may be found at www.desertec.org, www.desertec-uk.org.uk and www.desertec-uk.org.uk/news/news.html.

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