e-Parliament

Can Europe switch to clean energy and keep the lights on?

The most recent warnings from the climate scientists suggest that we need to end our dependence on fossil fuels very quickly. But could we power the European economy largely from sun, wind and water within 20 years? If we approach the problem from a regional rather than from a national perspective, the answer is yes. Here's how:

Build a "supergrid" linking the whole Europe-Mediterranean region, using high voltage direct current (HVDC) cables. HVDC lines, which lose very little energy in transmission, can bring in solar, wind, wave, hydro or geothermal energy from wherever these sources are abundant to the rest of the region.

Feed into the grid cheap, reliable energy from solar thermal power stations in the sun-rich areas of Southern Europe, North Africa and the Middle East. These power stations, like this one in Spain, use mirrors to concentrate the sun's heat to boil water and drive a steam turbine.

Expand our capacity to store renewable energy in Europe's mountain ranges by pumping water uphill into reservoirs, large and small. When electricity is needed, water is run downhill through a turbine, returning 75% of the original energy into the grid. As in this French reservoir, "pumped storage" is already widely used.

Rapidly expand wind power. Across the whole region, the supply is fairly steady: when the wind drops in one place, it is blowing elsewhere. Some wind energy can be stored in the mountains as backup to ensure 100% reliable supply, thus allowing us to depend on wind for a larger part of our energy.

Put solar photovoltaic (PV) panels on rooftops and in solar farms, like this one in Germany, throughout the region. The cost of PV is falling fast, and new developments such as "thin film" technology are about to reduce costs further. Some of the energy generated in the daytime can be stored for night time use, thus ensuring a steady supply.

Sun, Wind and Water

Conventional wisdom seems to assume that Europe can derive only a modest percentage of its energy from renewables in the next few decades. Underlying such statements is an unspoken assumption: that the level of political will for the shift to clean energy remains much the same as it is today.

This paper summarises how, given the political will, it would be quite possible from a technical point of view to power the European economy largely from renewable energy sources within two decades. A number of studies have explained this in much more detail, including two studies submitted in 2006 to the German government by the German Aerospace Centre, the DLR.

In the next few pages we will focus mainly on solar thermal power, wind, hydro and solar photovoltaic (PV) energy. These are all proven technologies which, combined through a renewable energy "supergrid" spanning the Europe-Mediterranean region, could provide the necessary energy on their own. Solar thermal power stations can generate electricity even at night by storing heat. Wind and PV can provide a steady supply of power if integrated with energy storage systems which pump water from a lower reservoir to a higher one, and then run the water downhill again through a turbine when energy is needed. When geothermal, biomass, wave, tidal and other clean energy technologies are added to the mix, the task gets even easier. Simple improvements in energy efficiency could make it easier still, by reducing the amount of energy we need to generate.

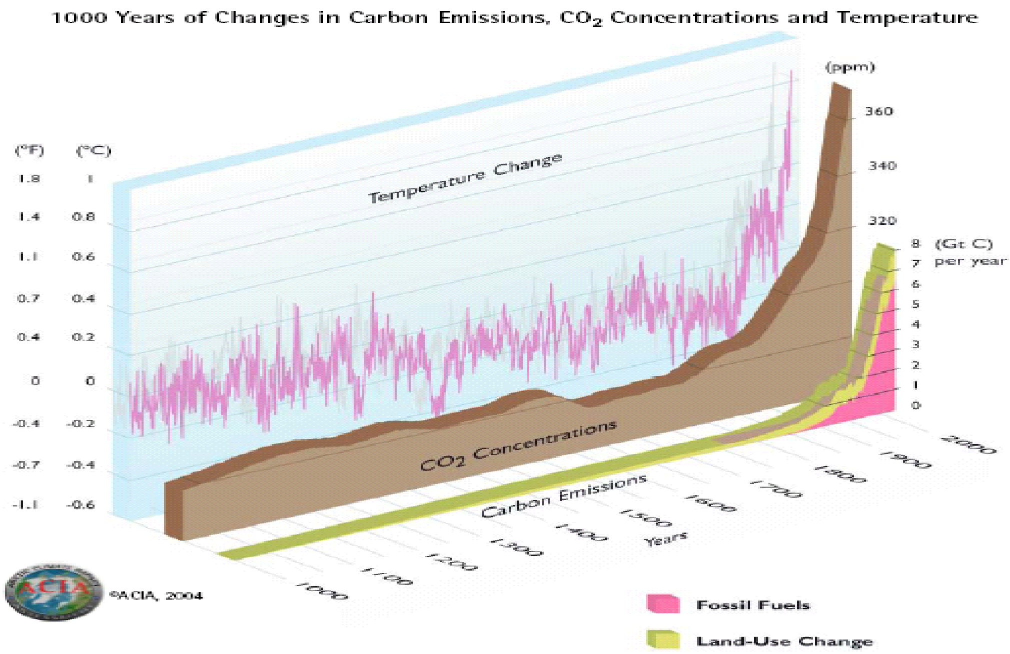
If so, the problem is not technical, but political. The question is: Will Europe's institutions and governments find the resources, and exercise the leadership, to put in place the incentives and infrastructure for a rapid shift to clean energy? If this can be done, it will provide a model for all other regions of the world to follow.

As we expand the industries which use sun, wind and water to generate electricity, the price of clean energy will fall -- indeed, it is already falling. Meanwhile, the price of oil, gas and coal is rising fast. As soon as renewable energy is cheaper than coal, governments can step back and let the market do the rest. In the process, we will have relieved Europe of one of its greatest economic worries today: the price of fossil fuels. And by putting Europe at the forefront of the clean energy revolution, European companies and countries stand to make a lot of money.

There is, of course, an even more important reason than the price of oil or the search for profit which makes a rapid shift to clean energy extremely urgent. And that is the danger that by burning fossil fuels we will destabilise the entire planet, depriving today's children of a decent future. Let us look first at a few facts from the climate scientists which explain why we have to make the transition to renewable energy much faster than Europe's governments contemplate doing today. Then we will turn to the combination of technologies which make that transition much easier than most governments think, under the headings Sun, Wind and Water.

The need for speed

The link between the planet's temperature and the concentrations of carbon dioxide and other greenhouse gases in the atmosphere is now clearly established. It is well summarised in the graph below.



The newspapers are full of numbers about climate change, but we have to consider only a few of them to see that, so far, our global political response to global warming lags far behind the action that is needed.

Even if we could stabilise greenhouse gases at their current concentrations in the atmosphere, estimates by the UK Met Office suggest that we would still have a greater than 70% risk of pushing up the Earth's temperature by a dangerous 2 degrees Centigrade or more. At that point we run a serious risk of triggering feedback loops, such as loss of forests, methane from the melting tundra, or acidification of the oceans, which could push us into runaway global warming.

To be safe, we need to reduce concentrations well below the current level. Jim Hansen, a leading climate scientist and head of the NASA Institute for Space Studies, argues that we need to move urgently from our current concentration of more than 380 parts per million (ppm) of CO2 in the atmosphere down to at most 350 ppm. Before our heavy use of fossil fuels began, the natural level was approximately 280 ppm.

Looking ahead, the Met Office estimates that the planet in 2030 will only be able to absorb some 9.9 billion tonnes of carbon dioxide each year. There will be about 8.2 billion people. To rapidly reduce greenhouse gases in the atmosphere, we will need to emit on average less than one tonne per person. Today, an American emits closer to 20 tonnes of CO2 per capita, a British citizen around 10 tonnes, and an Indian more than 1 tonne. Conclusion: to prevent dangerous climate change, we must do two things. First, the world has to shift to clean energy much faster than most governments realise or admit today. Second, we have to stop the destruction of tropical forests and other ecosystems, as that destruction contributes about a quarter of our total global emissions of CO2.

This problem requires action by governments around the world, and there are continuing global negotiations through the United Nations about how to act on a global scale. But the UN negotiations are slow, cumbersome, and based on a "consensus" process that tends to result in weak agreements and is easily blocked by any major player. When the consequences of failure could be catastrophic, it would be unwise to rest all our hopes on any single political strategy for stopping global warming. In the interests of the planet, and of the European economy itself, Europe should be prepared to move ahead now with or without new treaties, and to move faster on the ground than UN negotiations normally move.

Most economic activity can be powered from the national grid. Machines in factories, offices and homes can be powered by electricity, including machines for heating and cooling. Vehicles can run on battery power, or on hydrogen fuel cells. The hydrogen itself can be produced using clean energy to electrolyse water. The question is: can we put enough power into the grid to provide the necessary energy to everyone? To see how this can be done, let us look first at the most unlimited power source of all: the Sun.

Sun

There are two ways to generate electricity directly from the sun: solar thermal power, and solar photovoltaic. Both have their advantages, and the cost of both is falling. Solar thermal power (also known as "concentrating solar power" or CSP) is currently cheaper, and can generate electricity into the night by storing heat. Photovoltaic panels, on the other hand, can be used in a totally decentralised way. We will summarise each in turn.

Solar thermal power

Solar thermal power stations use mirrors to concentrate the sun's heat, boil water and drive a conventional steam turbine. Solar thermal electricity has been generated on a modest scale for more than 20 years in California's Mojave Desert, and the technology has worked without problems. New power stations have recently been built in Spain and Nevada, with more in planning or under construction. The Australian-American company Ausra, which recently established itself in Silicon Valley, has signed agreements to produce 1,000 MW of electricity for two major US utilities. Spain is building up its solar thermal power industry with a special feed-in tariff. India has recently announced plans for initial incentives to encourage the development of CSP there.

Pictured below is a solar thermal power station which opened in 2007 outside Seville, Spain.

Studies in the US have calculated that if an area in the Southwestern United States 92 miles by 92 miles square were to be covered with solar thermal power stations, it would produce as much electricity as the entire US produces today. Naturally, the power stations do not all have to be built in one location.

The best place for generating solar thermal power is dry regions which have little cloud cover, as they need direct sunshine. Best of all are deserts, which have the advantage that there is plenty of land that is not being used for other purposes.

The German Aerospace Centre's studies for the German Government looked at the potential of solar thermal power in the Europe-Mediterranean region. They concluded that this single energy source could provide a substantial part of the region's energy, using high-voltage direct-current (HVDC) powerlines to transport the energy with very little loss from southern Europe, North Africa and the Middle East to northern Europe. (See section on transmission below.)

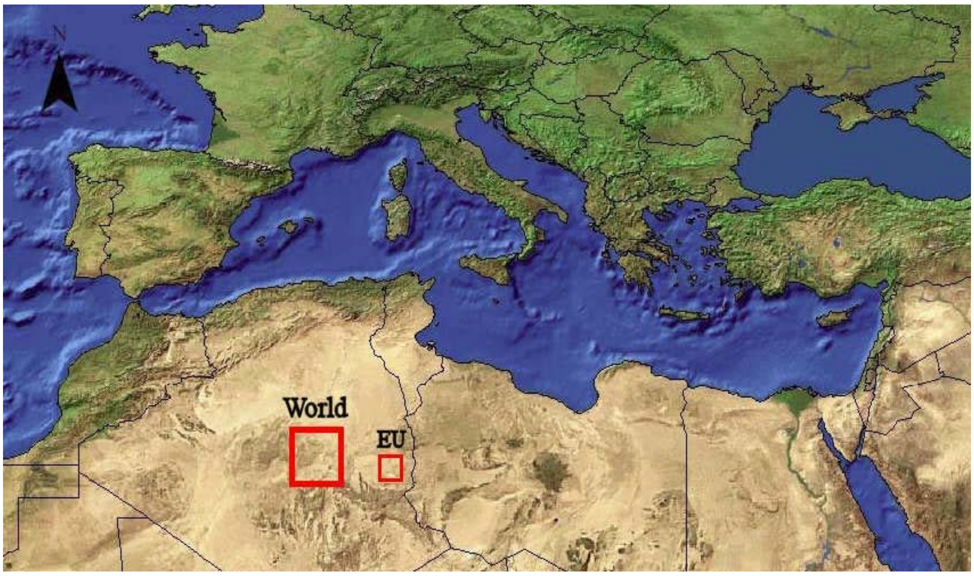
More than 90% of humanity lives within 3,000 kilometres of a desert. In the same way as in the Europe-Mediterranean region, HVDC power lines could bring energy to virtually all parts of the world. Thus solar thermal power could play a key role in a solution to the climate problem. There is no limit to how much energy we can generate in this way. It boils down to a political decision about how many mirrors we want to build.

One advantage of solar thermal is that energy can be stored as heat, in effect in a giant thermos, so that the steam turbines can continue running well into the night. If the heat runs out, fossil fuels can be used as a back-up to generate steam for the same turbine, ensuring power 24 hours a day. Solar thermal power stations can thus produce reliable baseload power.

Another advantage is that, in power stations on the coast, sea water can be used to cool the steam, so that the power stations can desalinate sea water through evaporation at the same time as generating power. In Southern Europe, the Middle East and North Africa water is rapidly becoming a scarce and precious commodity.

Ausra, the solar thermal company mentioned above, says that by using cheap, flat strips of mirror to concentrate the sun's rays on an overhead pipe, together with heat storage at night, they can produce electricity for US$0.08 per kilowatt hour (kwh), roughly the same as wind power and competitive on price with gas fired power stations. (Coal is still cheaper at around $0.05 per kwh, but according to an MIT study that would rise to $0.08 if carbon were priced at $30 a ton or if the CO2 had to be captured and stored underground.) Some other solar thermal power companies say they produce energy in the range of $0.09-0.13 per kwh. Prices are expected to fall quickly to as low as $0.07 per kwh as solar thermal power is deployed on a larger scale in the next few years.

The following map shows an estimate of how much desert land would need to be covered with solar thermal power stations to produce all the electricity that Europe and the world produce today.



There will be some in Europe who are less than enthusiastic about relying too heavily on the deserts of North Africa and the Middle East for energy supplies, given that political relations are sometimes troubled across the Mediterranean. A few points to keep in mind:

- **A transmission cable is not like an oil tanker**, which can sail in any direction. If a country chooses not to export its solar or wind energy, it will suffer from lost export income.
- **Europe is already interdependent with its neighbours**. If political relations should worsen, those neighbours have many ways to apply leverage. A regional electricity grid and cooperation on renewable energy development, like the early European Coal and Steel Community, could help to build closer political relations.
- **With high population growth, the impacts of climate change and the prospect of increasing water shortages**, the countries to the south and east of the Mediterranean have their share of challenges already. Without economic development and new water supplies, there could be trouble ahead. Helping to develop a major new clean energy export industry among Europe's southern neighbours would be in everyone's interests. As it happens, solar thermal power stations on the coast can also help to solve the water problem, as sea water can be used as a coolant, desalinating water in the process.
- **Any political risks from energy interdependence pale into insignificance beside the risks of climate change**. If the desert sun can help us to prevent dangerous global warming, we should use it without hesitation.

Solar photovoltaic energy

Thanks in no small part to good legislation in Germany and Spain, the world-wide installed capacity for solar photovoltaic (PV) energy is increasing by 50% a year. On rooftops and in solar farms, sunlight is being converted directly into electricity and, in many countries, sold into the national grid. As the industry grows, the price of the energy is falling. In 1995, PV energy cost $0.50 per kwh, in 2005 it had fallen to around $0.20, depending on latitude and solar irradiation. As the price of solar PV continues to fall, and the price of fossil fuels rises, many in the industry now expect to achieve "grid parity" – the point where electricity from the sun can be produced as cheaply as it can be bought from the grid – within 3 to 5 years.

A standard photovoltaic (PV) solar electric system is made up of a number of individual PV cells, which are small devices made of semiconductor materials such as silicon that absorb sunlight and convert it directly into electricity. Each cell usually produces about 1-2 watts of power, and these cells are connected together to form PV systems of varying size. While they generate most energy on a sunny day, they work even in cloudy conditions.

A rooftop PV installation

Technological improvements are expected to bring about dramatic cost reductions in the next few years. New developments are increasing the efficiency of silicon based solar cells. "Thin-film" technology uses very small amounts of raw material compared with traditional wafer-based cells, and usually no silicon at all, which gives it the potential to significantly reduce the cost of PV energy. Research into thin-film processing has been underway for a number of years, and mass production has now begun. One product uses what is described as a thin layer of solar-absorbing nano-ink, which is laid onto thin metal sheets with a printing press-style machine. Other companies are using mirrors or optics to concentrate the sun's rays on small amounts of PV material, thus reducing costs.

Nanosolar's PowerSheet thin film PV cell

Increases in the German feed-in tariff for PV – which guarantees a good price over 20 years for solar energy fed into the grid – have had a huge effect on the PV market. The first increase in 2000 resulted in a huge boom in solar manufacturing, and when the tariff was increased further to between €0.54 and €0.62 per kilowatt hour (kwh), the annual growth of the German PV market exceeded 50%. Germany remained the fastest-growing PV market in the world during 2005-2006, and by the end of 2006 some 55% of the global surface of PV panels was to be found there.

Chinese company QS Solar claims that once critical mass is reached in the construction of its major PV plants, the company will be able to sell electricity at 1 yuan (14 US cents) per kwh. The Californian company Nanosolar claims its thin film technology will soon enable it to produce generating capacity at $0.99 a watt, roughly equivalent to the cost of a coal-fired power station – a gigawatt (one billion watt) coal plant costs about $1 billion to build. Again, there is no limit to the power which can be generated using PV: it is simply a political decision how many solar panels we want to build, and where.

The only limitation of solar PV is that it ceases to generate power as the sun sets. This is one reason why it is important to link all parts of Europe, through a supergrid, to mountainous areas where energy can easily be stored by pumping water into uphill reservoirs (discussed in more detail below). If storage capacity is increased, then solar PV and wind can both provide a steady supply of power 24 hours a day.

Wind

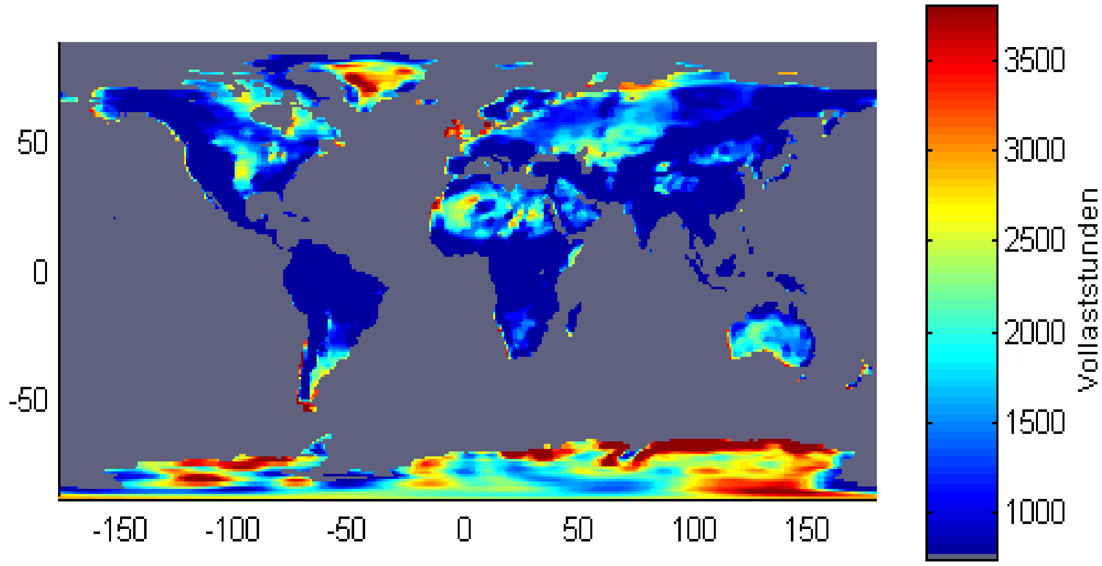
World wind power capacity is growing at 30% a year and will exceed 100 gigawatts in 2008 – more, for example, than the total generating capacity of Britain from all sources. There is enormous potential for further growth in Europe and North Africa, particularly if different wind-rich areas are linked together by a supergrid to increase stability of supply. Across the region as a whole, the supply of wind is fairly stable: when the breeze drops in one place, it is blowing in another. Equally important, through a supergrid wind energy could be carried from areas rich in wind to those with less wind.

Wind turbines convert the kinetic energy in wind into mechanical power, which is in turn converted into electricity through a generator. Mounted 30 meters or more aboveground, they can take advantage of faster and less turbulent wind. Growing numbers of wind turbines are also being deployed offshore.

Wind energy is one of the most economical new sources of electricity available today. About 80% of the total cost per watt of installed wind power is comprised of the cost of the turbine itself. As with solar, the fuel is free. As the hardware becomes cheaper to produce, and turbines more efficient, the cost of wind power is decreasing at a rate of about 3% each year. The cost of wind generated electricity already fell by over 50% in the 15 years leading up to 2003. Today the price of onshore wind energy is below €0.07 per kilowatt hour, making it competitive with natural gas.

Even the US Department of Energy, hardly a radical exponent of renewables, released a study in May 2008 saying that wind could provide 20% of the US electricity supply by 2030.

The world wind map below shows that Europe and Morocco have excellent wind resources compared to most regions of the world.



The inherent variability of wind power can be compensated for if wind is combined with hydro as backup, so that when the wind drops water is unleashed to maintain a steady electricity supply. How this could best be done is discussed in the next section.

Other technologies are also being developed to enhance the reliability of wind power. Compressed Air Energy Storage (CAES) is being developed in the US state of Iowa as a way of storing the energy produced by wind turbines for future use. Some turbines are used to compress air into underground chambers, which can then be released through a separate turbine whenever additional electricity is needed.

Water

Harnessing rivers and streams

Hydroelectric power is an important part of the electricity supply for most of the more mountainous countries in Europe, and it should be developed to the full. This does not mean only large dams. Small-scale hydro and run of river systems can also play an important role.

Energy storage

Equally important, there is almost unlimited potential for using water to store electricity generated by wind, waves or solar PV, in order to provide a steady supply of energy when the wind drops or when the sun goes down. No river is needed; all that is required is one reservoir at the top of a valley and one at the bottom. When the wind is strong and the sun is high, water is pumped uphill. When more energy is needed, the same water runs downhill again through a turbine. In this "pumped storage", some 75% of the energy put into the system can be retrieved when it is required, which makes it one of the most efficient forms of energy storage.

Pictured below is the Marchlyn Mawr Reservoir at Dinorwig Power Station in North Wales, which operates in exactly this way.

If sufficient incentives were created through a feed-in tariff or other instruments, any farmer in hill or mountain country could build two reservoirs to store energy on a small scale, ready to be automatically fed into the grid whenever it is needed. For practical purposes there is no limit to how much energy could be stored in this way.

This has profound implications for the more intermittent renewables, such as wind, PV or wave power. Provided there is sufficient storage capacity as backup, we can build as much wind or PV infrastructure as we need. We simply need to build additional generation and storage capacity to ensure that we can store enough energy to keep the supply steady during the night (in the case of PV) or when the wind drops.

This does not have to be the only back-up power source for wind and PV. It goes without saying that, as the transition to clean energy progresses, we will not be short of back-up capacity from fossil fuels. The existing coal, gas and oil power plants do not need to be dismantled. At least some of them can be available as needed to provide power whenever renewable sources are insufficient to meet demand.

Wave and tidal

Wave and tidal power are now on the brink of large-scale commercial deployment, with a Portuguese feed-in tariff for wave power putting Portugal among the leaders. According to estimates by the UK's Royal Academy of Engineering, and by the UK Government, both wave and tidal should be able to produce electricity for less than €0.10 per kilowatt hour in the short term. The ocean coasts of Europe should soon be able to contribute substantial energy to the mix. Like wind and PV, they need to be combined with energy storage to provide a steady supply. Indeed, in locations where hills and mountains come down to the sea such storage is particularly easy, as it only requires pumping sea water up to a reservoir and then releasing it through a turbine back into the sea.

High voltage direct current transmission lines

If we are to generate clean energy in the areas where it is most abundant – such as deserts for solar energy, and windy coastlines for wind power – store it in hilly regions, and transmit it to the rest of Europe as needed, we need a way to transport electricity over long distances without significant losses along the way. The answer to this can be found in cables that currently connect the British and French national grids under the English Channel, and connect Scandinavia, Northern Germany and the Netherlands. These are called High Voltage Direct Current (HVDC) transmission lines. They lose only about 3% of the electricity over every 1,000 kilometers, and unlike traditional Alternating Current (AC) power lines, they work well underwater.

A DC grid between Scandinavia and the Netherlands is already used to store surplus power until it is needed by pumping water uphill in Norwegian hydroelectric plants.

Traditional low voltage AC lines lose large amounts of electricity in long-distance transmission, because electricity is dissipated as heat due to the resistance of the conductors. High voltage lines require less surface area for transmission, which results in less heat being created, and therefore less transmission loss. Nonetheless, High Voltage Alternating Current (HVAC) lines remain rather inefficient over long distances.

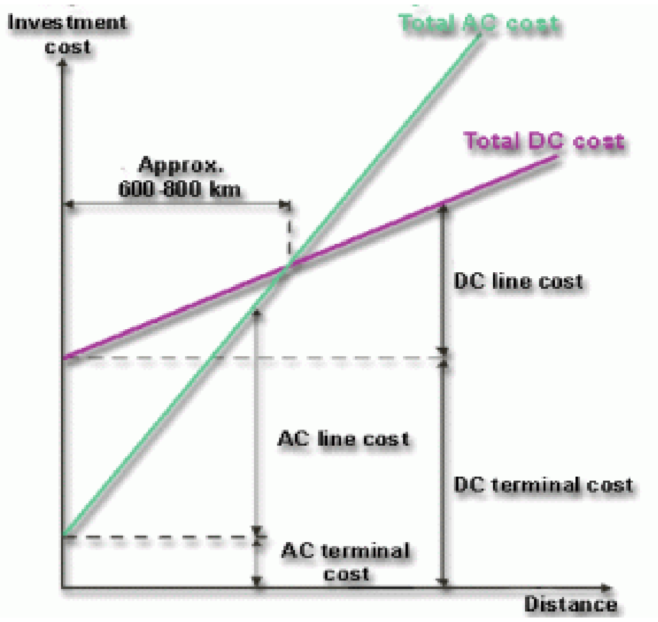
Despite this, since AC power can easily be transformed from low to high voltage for transmission, and then converted back again for local use, AC has generally been the first choice for most utilities and transmission companies. However, with the use of modern static inverters, it is now possible to invert AC to DC and then back again with very high efficiency – making HVDC increasingly attractive. When transporting energy over large distances, the savings made due to the increased efficiency of HVDC lines more than offset the additional cost of the inverters.

DC Line at the Dickinson HVDC Converter Station, Minnesota

Originally developed in the 1930s, HVDC lines are now a mature and reliable technology ideally suited to transporting energy over long distances. With modern HVDC lines, for example, solar or wind electricity could be imported from North Africa to northern Europe with only about 10% loss of power. HVDC lines are not only more efficient than HVAC lines, but are also safer and more reliable when buried under ground or laid under the sea.

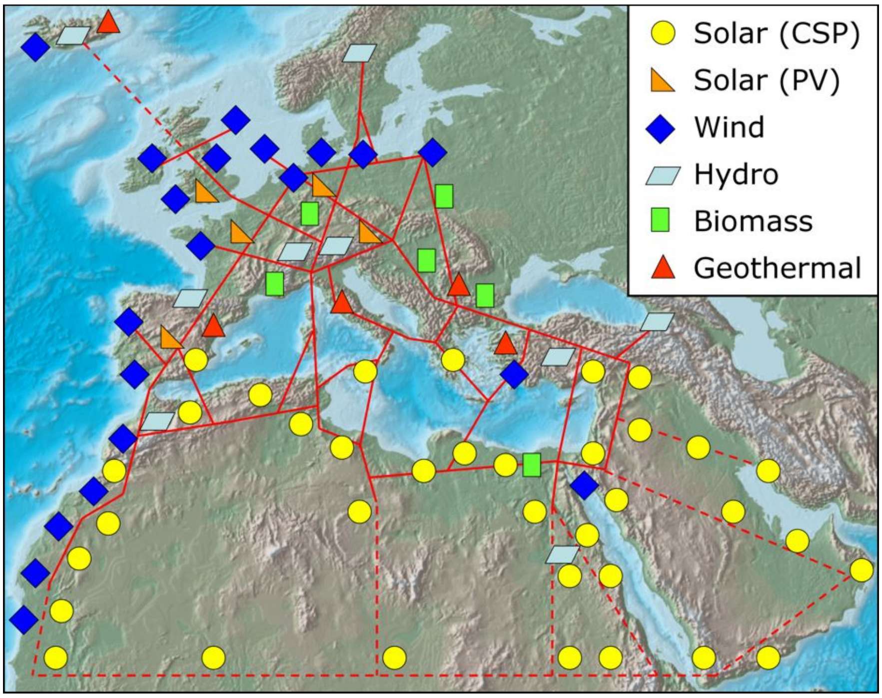
HVDC lines can be used to connect remote generating centres, or to connect large HVAC grids that are out of sync with each other, such as connecting national grids that run on different frequencies, for example. Increasing the interconnections between Europe's national grids will have the added benefit of increasing the stability of electricity supply across the region, even before new energy sources are added to the mix.

While HVDC lines are already economically attractive when used over long distances, costs are likely to decrease even further as the cost of static inverters and other hardware comes down.



Typical investment costs for an overhead line transmission system with HVAC and HVDC.

The "DESERTEC" concept having been developed by the Trans-Mediterranean Renewable Energy Cooperation (TREC) project of the Club of Rome, two studies for the German government were carried out by the German Aerospace Centre (the DLR), examining in detail the possibility of creating a regional supergrid connecting the entire Europe-Mediterranean region. They proposed the construction of a system that would look something like this:



The study says:

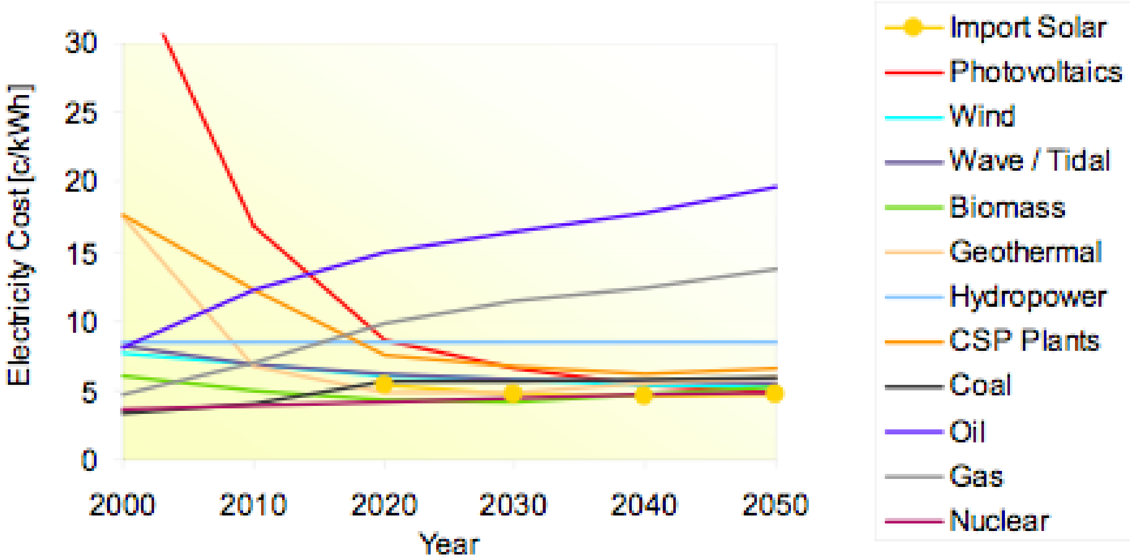
> As a spin-off effect of this development, the import of solar electricity from the Middle East and North Africa (MENA) will become an attractive diversification of the European power generation portfolio. Solar and wind energy, hydropower, geothermal power and biomass will be generated in regions of best performance and abundance, distributed all over Europe and MENA through a highly efficient HVDC grid on the upper voltage level, and finally delivered to the consumers by the conventional interconnected AC grid on the lower voltage level. Analogue to the network of interstate highways, a future HVDC grid will have a low number of inlets and outlets to the conventional AC system as it will primarily serve long distance transfer, while the AC grid will have a function analogue to country roads and city streets. Only 10% of the generated electricity will be lost by HVDC transmission from MENA to Europe over 3000 km distance. In 2050, twenty power lines with 5000 MW capacity each could provide about 15 % of the European electricity demand by solar imports, motivated by their low cost of around 5 €-cent/kwh (not accounting for further cost reduction by carbon credits) and their high flexibility for base-, intermediate- and peak load operation.

Naturally, such a supergrid does not have to be built all at once, but can be built in stages. Current moves in the EU to “unbundle” ownership of the national grid from ownership of the generating capacity should make it simpler to link up the different national grids in this way.

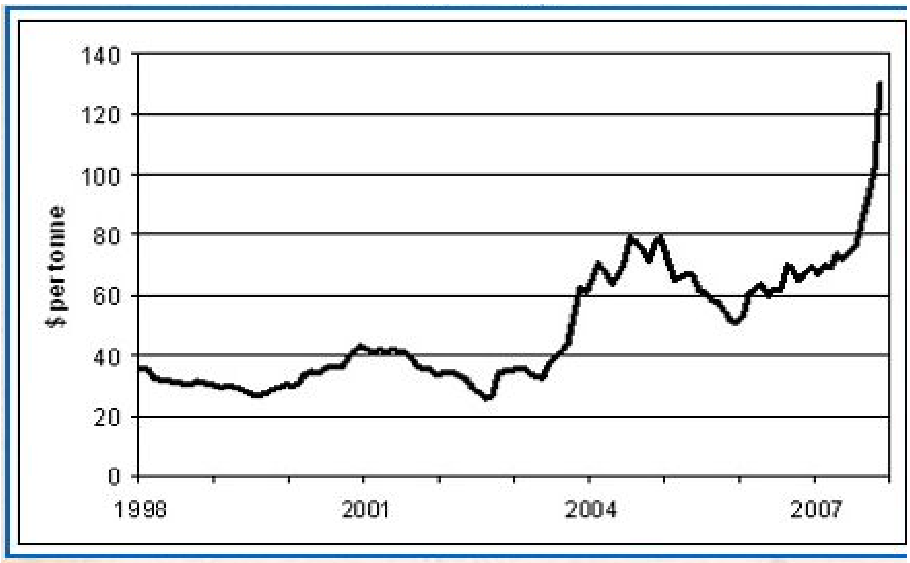
Costs

The authors of the DLR study estimate that ten to twenty years from now the overall cost of Europe’s energy if produced mainly from renewable sources will be significantly less expensive than a business as usual scenario. By 2050, they said, the Europe-Mediterranean region could save at least $250 billion on its energy bills, even when the cost of the supergrid is included. This is based on calculations which conservatively assume a starting price of $25 a barrel for oil and $49 a ton for coal, with an increase of only 1% per year. As oil now surges beyond $130 a barrel, and the cost of all fossil fuels rises day by day, the long-term cost advantages of non-fossil energy become ever more attractive.

The DLR studies estimate future costs of different energy sources as summarised in the graph below.



As the graph shows, solar energy imported from North Africa is estimated to be cheaper than coal right from the assumed start date of 2020. As the price of coal rises, this is increasingly likely. Once again, this graph is based on conservative assumptions about the price of fossil fuels. In reality, the price of coal over the last 10 years looks like this:



Northwest Europe Steam Coal Marker Price. Source: McCloskey Group

The study authors estimate the cost of an initial supergrid spanning the Mediterranean and reaching as far north as Germany and the UK would be in the range of €45 billion. If this were spread over 20 years, for 500 million Europeans it would amount to less than €5 per person per year. If we wanted to import more energy, even double or triple that amount is not beyond the combined resources of the governments of Europe. Most Europeans would probably be prepared to pay a few euros a year to help ensure that future generations inherit a livable planet.

The idea of a renewable supergrid is critical to the vision of a Europe powered largely by clean energy. Once we remove the barriers to energy transmission from areas of abundance to areas of high consumption, and include the potential for pump-storage in hill and mountain country, we can clearly generate as much energy as we need. If we need to increase supply, we simply put more mirrors in the desert, or more wind turbines offshore, or more solar panels on rooftops.

Renewable energy is unlimited in a way that even nuclear energy is not. One study (by energy analysts Jan van Leeuwen and Philip Smith in 2005) estimated that if all the world's electricity was produced by nuclear power plants, global uranium supplies would last for 6.8 years. Whether the actual number is larger or smaller makes little difference. Even if we choose to ignore the problems of nuclear waste and the risk of nuclear terrorism, nuclear power hardly offers a permanent solution. By contrast, once we have created the infrastructure to draw our energy from sun, wind and water, we have cheap energy forever.

In short, the climate problem is not so difficult to solve as many people think, and in solving it we are likely to get richer, not poorer. The solutions that work for Europe will work in much the same way for all regions of the world. And once Europe leads the way to cheap, clean energy, other regions would be foolish not to follow. At some point, global oil supply will peak, and when it does those who are still dependent on fossil fuels will be paying a very high price indeed.

The costs of not controlling global warming are higher still:

- **Extinction** of a substantial percentage of the world's species.
- **Loss of territory** to sea level rise by all European coastal nations. A recent NASA study found that the last time the planet was 3°C hotter, the sea level was 25 metres higher.
- **Loss of lives and property** in intensifying storms, floods and heat waves.
- **Rising food prices** as droughts, floods and higher temperatures damage global food production.
- **Increasing desertification** in southern Europe as the Sahara moves northwards.
- **Growing numbers of environmental refugees** as these effects hit hard in the tropics and in North Africa.

It is sometimes hard to believe that Europe faces such a dire scenario. Unfortunately, the best science available tells us that this is exactly what we are facing if humanity does not rapidly end its dependence on fossil fuels.

As we said at the outset, the challenge is not technical but political: to mobilise the incentives and investments required to make the shift to clean energy. The problem cannot easily be solved country by country. To implement the solutions described here, the institutions of the European Union need to take a leading role. The European Commission and interested national governments should launch studies immediately to work out the best way to apply these technologies in combination, linked by a European supergrid.

But where will the political leadership be found to begin this process? If the challenge is political, and action is needed on a regional scale, the place to begin is surely the European Parliament.

The two studies on a clean energy supergrid by the German Aerospace Centre can be found at:
http://www.dlr.de/tt/trans-csp
http://www.dlr.de/tt/med-csp

Links to information on solar thermal power can be found at www.desertec.org

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