New power under the sun

A vision for large-scale solar power from the world's deserts

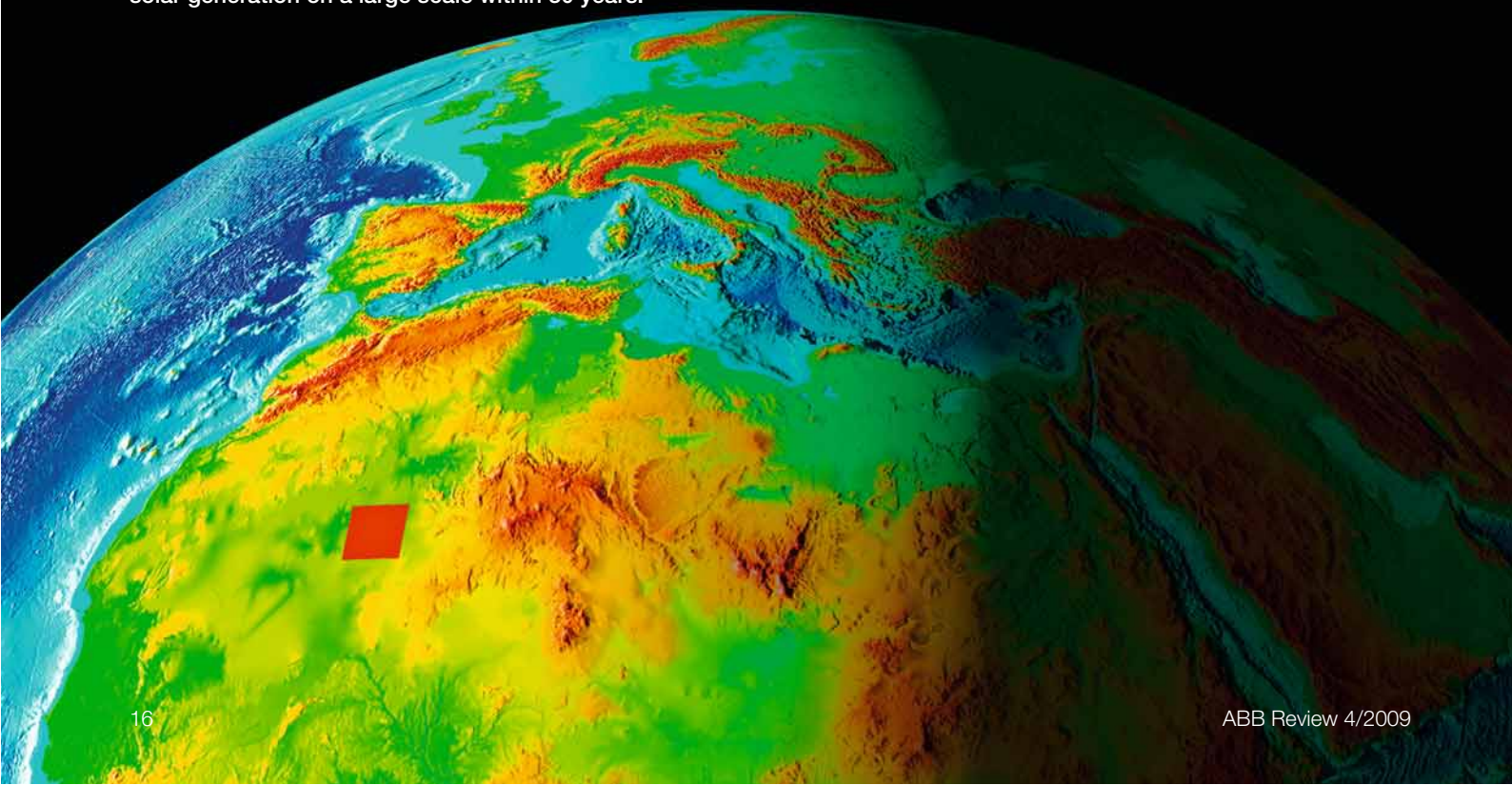
Andreas Moglestue

Without the sun, civilization and indeed life itself would not be possible. Most of our energy, be it fossil fuel, biomass or wind, derives directly or indirectly from the sunlight that reaches the Earth's surface. Mankind has, until now, met most of its growing energy needs by harnessing these derivative sources – mostly in the form of fossil fuels.

With standards of living set to rise further, especially in developing countries, global demand for energy will continue to grow. Furthermore, with the planet's population likely to reach 10 billion by 2050, merely securing basic necessities like as clean water will call for energy-intensive technologies such as desalination plants. How can this ever-growing thirst for energy be satisfied without inflicting grave environmental damage? How can the world's long-term energy supply be assured in the face of limited reserves of fossil fuels?

It is estimated that solar power plants in a desert area of only 90,000 km^2, that is the equivalent of 300 km by 300 km and only a small fraction of the world's deserts, could meet today's global electricity needs. Furthermore, 90 percent of the world's population lives within 3,000 km of a desert – a distance over which economic transmission is considered feasible with HVDC technology.

The Desertec Industrial Initiative is a working group in which ABB has joined forces with several partners for the advancement of such a project in the EUMENA region (Europe, Middle East and North Africa). The Desertec concept envisages solar generation on a large scale within 30 years.



Human activity across the globe is consuming a staggering 15 terawatts (15,000 GW) of power. To put this into perspective, North Sea oil production contributes about 420 GW[1], and coal production in the United States circa 760 GW.[2] Global electricity generation is about 2,200 GW.[3]

Fossil fuels, which currently cover 80 to 90 percent of global demand, are finite in supply. Nevertheless, they will continue to be the main source of energy for a long time to come: In absolute figures, use of fossil fuels will even rise in the medium-term future. Other sources, be they wind, biofuel or nuclear are all likely to have a role to play in reducing carbon dependency, and many are indeed already growing rapidly both in absolute terms and in market share.

The equivalent of the energy that all of mankind consumes in a year is being delivered every 90 minutes.

There is, however, one source that is providing some 170,000 TW of power to the Earth, 90,000 TW of which reaches the Earth's surface: That is 6,000 times total human consumption. In other words, the equivalent of the energy that all of mankind consumes in a year is being delivered every 90 minutes. In fact, in the time that the average reader will have taken to reach this point in this article, the Earth's surface will have received the equivalent of six months of North Sea oil production.[4]

Sun and steam

This plentiful source of energy is, of course, the sun. Photovoltaic panels are becoming a common sight on the roofs of buildings or powering such devices as pocket calculators or parking meters, and increasingly also feeding electricity into the grid.[5] One drawback of solar energy is that it is not constantly available. This problem does not merely occur at night: During the day, cloud conditions can adversely affect performance. Nevertheless, there are regions on this planet in which the latter problem is of little significance. Not only do deserts enjoy the highest levels of delivery of solar radiation, but the weather there is relatively constant and predictable: The sun shines fiercely all day.

Rather than using photovoltaic panels, it is envisioned that the proposed desert power plants will use concentrating solar power (CSP) systems. In such a power plant, reflectors will concentrate the sunlight to heat water to steam. This will be fed into turbines similar to those used in conventional thermal power plants. CSP generation is not only more efficient and economic under desert conditions, but – in contrast to photovoltaic cells, which stop generating as soon as it gets dark – heat can be stored to permit generation to continue at night. Furthermore, the adoption of turbine-based generation systems means that (where appropriate) additional steam can be supplied by combustion-based processes, permitting either a backup source of power or even a mixed generation facility. Cogeneration (involving the use of heat that was generated as a byproduct of other activities) is also an important option.

90,000 TW of solar radiation reaches the Earth's surface: That is 6,000 times total human consumption.

A valuable development initiative

The regions in which these CSP plants are to be built can benefit immensely. Besides immediate advantages such as jobs directly connected to the project, these areas stand to reap more far-reaching benefits thanks to the availability of affordable and sustainable

Footnotes

1) North Sea oil production is about 6 million barrels per day. The thermal equivalent of a barrel is about 6.1 GJ of energy.
2) About 1,000 megatons of coal are mined in the USA annually. The thermal equivalent of a kilogram of coal is 24 MJ.
3) 19 trillion kWh
4) Assuming the average reader reads 250 to 300 words a minute
5) See also "From light to power" on pages 22 to 24 of this edition of *ABB Review*.

The Andasol power plant near Guadix in Spain. The parabolic mirrors concentrate the sun's rays permitting steam generation. This is converted to electricity by turbines.

ABB's involvement with Desertec

In July, 2009 ABB signed a "Memorandum of Understanding" for the establishment of the Desertec Industrial Initiative. Why is ABB participating?
ABB was already working on the idea of a European grid integrating different kinds of renewable energies in the early 1990s. This included utilizing the sun's energy in deserts to supply Europe with emission-free power. It is only logical that ABB has been talking with the Desertec Foundation and supporting the project for many years. We are convinced that our technology and know-how can contribute to the success of this forward-looking project.

Is this vision of supplying clean power from the desert to Europe technically feasible by today's standards?
The technologies for such a project are already available today and have been tried and tested. We know how to transmit energy over large distances. More than 50 years ago ABB invented high-voltage direct current (HVDC) transmission, the key technology for long-distance power transmission. Since then HVDC has been continuously enhanced to enable the utilization of renewable energies, the interconnection of power grids and to increase efficiency.

In the case of Desertec we are looking at a distance of 3,000 km. How much electrical energy will actually be lost in transmission?
Thanks to our HVDC technology, the power can be transported over large distances with relatively low losses. At a voltage of 800 kV we expect the losses to be around 3 percent per 1,000 km. At a distance of 3,000 km, this means less than 10 percent losses. Long distance connections, however, will likely be an exception. A much more realistic option will be to feed the power from North Africa into the European grid via Southern Europe.

Does ABB have any experience with such long transmission distances?
Currently, ABB is building a high-voltage direct current transmission system in China to transport 6,400 MW of power over a distance of 2,000 km. This is approximately equivalent to the capacity of six nuclear power plants. In addition, we won a contract this July for the world's longest power line. Here, HVDC will connect two new hydropower plants in the northwest of Brazil with the economic metropolis of São Paulo, bridging a distance of 2,500 km.

The technologies for such a project are already available today and have been tried and tested.

Desertec requires very high investment costs. Will it be economical to produce power for Europe in the Sahara?
We wouldn't be supporting the project if we weren't convinced that it can be economical in the medium- and long-term. In the case of Desertec we are looking at a long time frame – decades rather than years. The first pilot projects will be implemented in a couple of years, and by 2050 the solar power plants in the Sahara will be expected to cover 15 percent of the European power requirements. Experts predict the power from solar plants to be competitive within the next 20 years. During this period, the power from conventional energy resources will become more expensive.

How can the energy generated in the desert be fed into the existing European grid considering the fact that the grids are already used to their full capacity today?
Due to increased electricity trading and rising energy demand, the European grid infrastructure will have to be upgraded across international borders anyway – not least because of the planned offshore wind farms in Germany, Belgium and Spain. It can only be advantageous to consider the integration of the Desertec project from the very beginning.

What about investing more in solar energy storage? Is there any research in this area currently going on at ABB?
First of all, the solar radiation in the deserts is more intense and more regular than it is here in Europe. There are no long, cloudy periods and hardly any seasonal variations. In addition, the use of solar thermal energy allows short-term energy storage. This means that the heat generated during the day can be stored in molten salt storage systems so that the turbines can continue turning during the night. But I expect further improvements in the field of power storage in the future.

Do you think that the solar energy from the desert will replace conventional nuclear, gas-fired and coal-fired power plants?
Desertec is a visionary project, which takes Europe closer to a carbon-neutral power supply. But it will take some time until the first power from the desert will flow to Europe. Therefore, the energy demand must be covered by a broad mix. That's why we will still need conventional energy generation today and in the future.

Sceptics say that the different interests of the countries involved in Europe, North Africa and the Arabian world could represent an obstacle to this project . . .
This is indeed a challenge and a reason why the initiative plans to spread the power plants across the entire North African and Middle Eastern region and to transport the power to Europe via several "energy bridges." I am confident that the political hurdles will be overcome when the project shows that it is economically profitable. This is something the African and Arabian countries will benefit from as well.

In what way?
Solar energy could become a major export for these countries, generating added value from a resource that is

available in abundance – sunlight. This will create new jobs, drive technological development and increase prosperity. And we must not forget that these countries will be able to use the Sahara power themselves, for example to desalinate seawater. The production of drinking water from seawater is very energy-intensive. The power from the Sahara could solve two problems at once.

The financing of the project still remains unresolved. Will ABB contribute to the costs?
It is ABB's aim to supply the technology for the Desertec project, and by doing so help to ensure its feasibility and reliability. These are important prerequisites for investors.

Peter Smits was interviewed by Melanie Nyfeler, Communications, ABB Switzerland

Peter Smits is the regional manager of ABB in Central Europe and the CEO of ABB AG, Germany.

Peter Smits co-initiated the Desertec Industrial Initiative on behalf of ABB.

energy. For example, desalination plants can be built for drinking water and to serve agriculture, totally revolutionizing the economic prospects of what are today disadvantaged areas.

The technology
As ambitious as the technical realization may sound, the largest hurdles lie in creating the political and economic framework to make such a development possible. The technologies themselves are the lesser challenge, being either available today, or adaptable from such technologies.

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The basic idea of solar concentration is not new at all: It dates back at least 22 centuries to when Archimedes proposed using an array of movable mirrors to focus the sun's rays and set fire to enemy ships. Although modern CSP plants serve more peaceful purposes, they use much the same principle: Movable mirrors constantly adjust their orientation according to the sun's position, permitting the maximum of energy to be captured. The reflected light is concentrated on a focal point whose temperature can reach several hundred degrees Celsius.

Power plants using variants of this principle have been in use in California since the 1980s, with further installations being added in various locations over the years. ABB has been involved in the realization of several of these, for example the Extresol project in Spain Factbox 1.

Capturing the sun's rays and converting these to electricity are only one part of the story. Once generated, the part of the electricity intended for Europe must be moved over large distances. This is where HVDC (high-voltage direct current) technology comes into play. Converter stations transform the generated electricity to high voltages, which can then be transmitted over long distances at very low losses. The losses of an HVDC line are about 3 percent for 1,000 km. Furthermore, the power can be transmitted by underwater cables, which would be useful for crossing the Mediterranean and bringing the power to Europe. ABB is a leader in the domain of HVDC technology and has completed or is working on several major projects transmitting power over thousands of kilometers Factbox 2.

CSP could meet 15 percent of Europe's electricity demands by 2050.

The Desertec Industrial Initiative
ABB has joined forces with several other manufacturers as well as utilities and finance partners to work towards a realization of these plans in the EUMENA region (Europe, Middle East and North Africa). The Desertec Industrial Initiative strives to build on the recent creation of the Union for the Mediterranean, which was set up to improve and simplify cooperation between the countries of this region. Besides providing public information, the Desertec Industrial Initiative will

Factbox 1 The Extresol power plant

Extresol is a 100 MW CSP installation currently being completed in Spain's Extremadura area. ABB is supplying the control equipment with which the 1,248 parabolic troughs will follow the sun's movement through the sky to an accuracy of 0.03 degrees. Besides this, the company's scope of delivery includes instrumentation, the automation system, motors, drives, low-voltage equipment and substations.

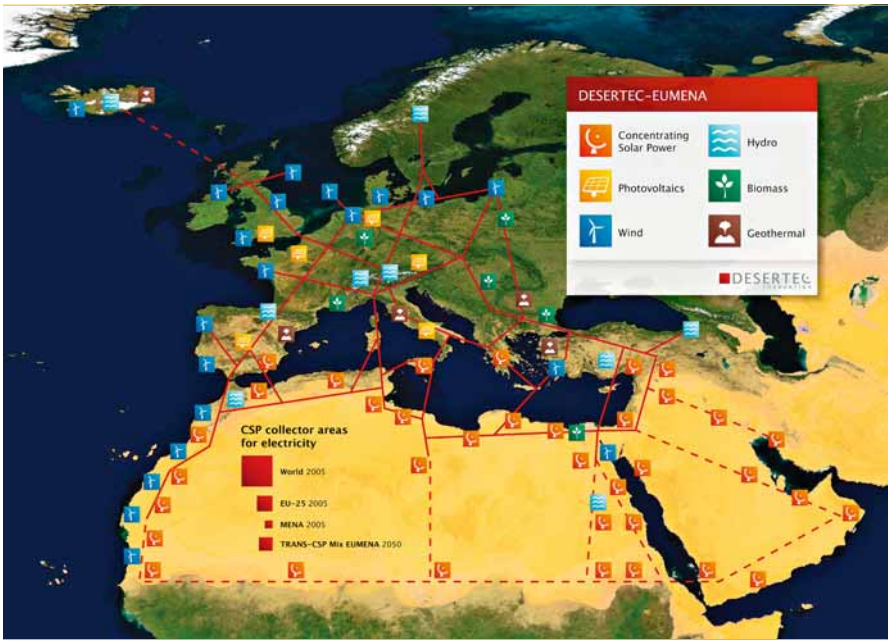
The plant will store excess heat in liquid salt tanks permitting generation to continue when the sun has set.

The first 50 MW are scheduled to commence operation at the end of 2009, with the second 50 MW following six months later.

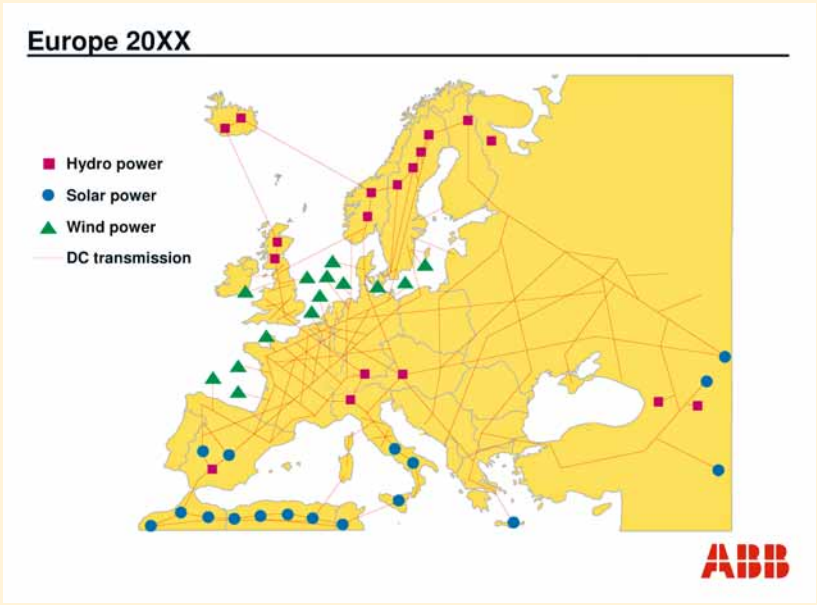
perform feasibility studies on such matters as the political, organizational, financial, technological and ecological aspects of the project. It aims to develop a rollout plan describing how to meet the target of covering about 15 percent of Europe's electricity demand by 2050. In a second step, a number of smaller reference projects will be identified and specified, permitting the feasibility of the concept to be tested and demonstrated.

The Desertec Industrial Initiative's ultimate plans for the EUMENA region feature a network of electrical super highways interconnecting the principle areas of generation and consumption across the region 1. Besides linking CSP plants, this super grid envisages the connection of large onshore and offshore wind farms as well as major hydroelectric plants and even a number of biomass and geothermal facilities.

1 Desertec's vision of a network of power super highways connecting major CSP, wind and other generating facilities to the principle load centers. Source: Desertec.



2 The historic slide dating from 1992 in which ABB presents its vision for a future European power supergrid. The concept bears remarkable similarities to that of 1 (Gunnar Asplund, ABB).



A network of electrical superhighways will interconnect the principle areas of generation and consumption across the region.

The integration of these installations into the existing grid will entail many challenges, including adapting operations of conventional power plants, and making the grid better suited to the increased use of renewable energy. These are all areas in which ABB can contribute its expertise.

Pioneering role

The Desertec Industrial Initiative was formally established as an organization earlier this year. It does, however, go back in a less formal state to the 1990s, when it was brought into exis-

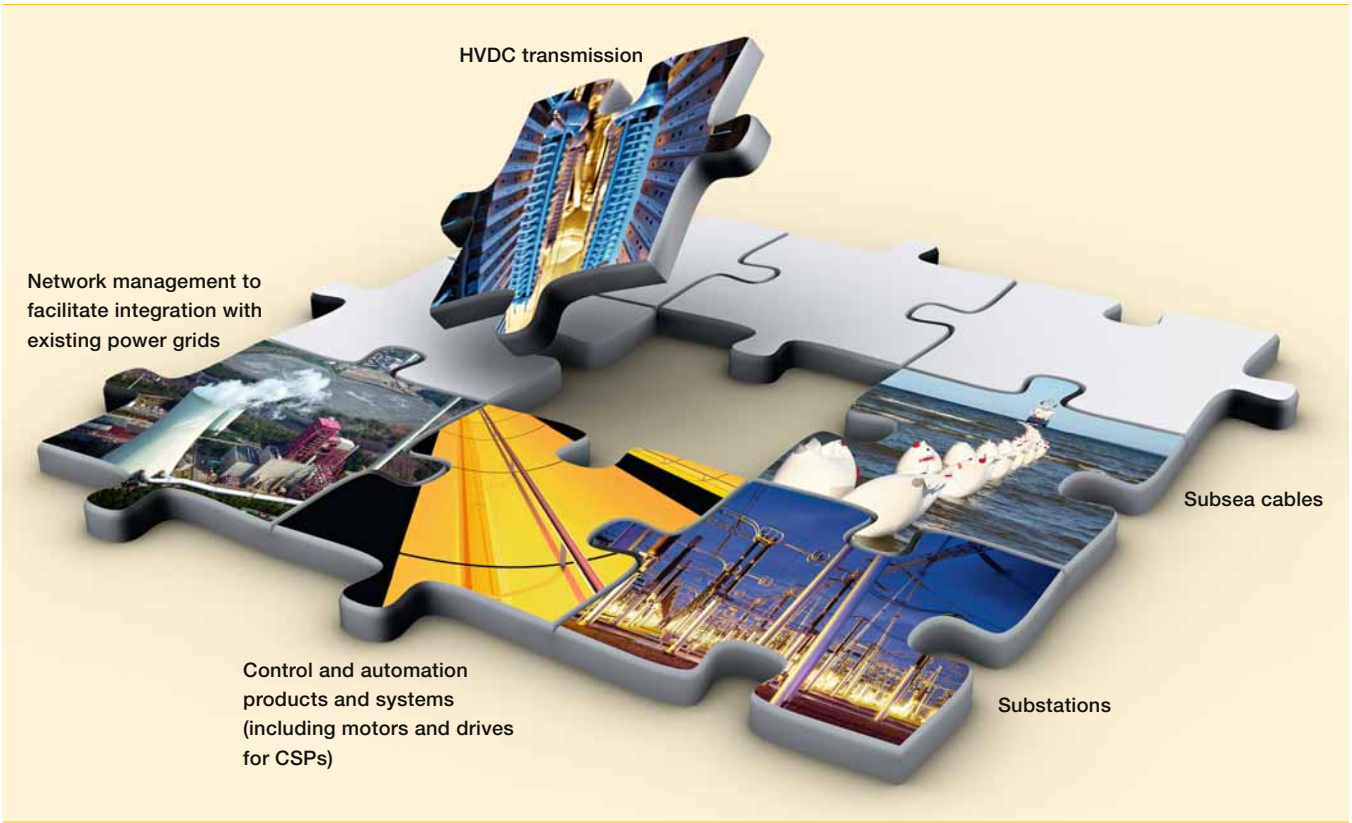
Factbox 2 Major HVDC projects

ABB recently completed a link between China's Three Gorges hydroelectric plant and the city of Shanghai, permitting 3 GW to be transmitted over 1,060 km. This followed on from two other major HVDC links built by ABB, connecting the same power plant to Changhzou and Guangdong. All of these links are rated at 500 kV and 3,000 MW.

ABB has recently won a contract to supply key technology for the Rio Madeira link, a 2,500 km project connecting a hydroplant in Brazil's Amazon region to the city of Sao Paulo. The link will carry 3,150 MW at 600 kV.

ABB has also supplied many underwater HVDC links, most notably the recently completed NorNed link under the North Sea between the Netherlands and Norway. This 580 km link (the world's longest underwater link) carries 700 MW. The cables themselves are also a key ABB technology.

3 The main technologies and know-how that ABB can contribute to Desertec from its present portfolio include:



tence by the German section of the Club of Rome (a global think-tank dealing with political issues, including environmental concerns and the dangers of famine, water shortages, etc.). A study on the topic[6] by DLR (the German Aerospace Center, Deutsches Zentrum für Luft- und Raumfahrt e.V.) and published in 2006 provided encouraging results.

ABB's part in this goes back further, however: As long ago as 1992, the company presented a vision of Europe's future power grid 2. It was drawn up by Gunnar Asplund, who was then development manager for ABB's HVDC technology and presented in a study circle created by ABB to look into the long-term future of power transmission. His vision bears remarkable similarities to that which the Desertec Industrial Initiative is now pursuing.

Green power from a bright sun

The Desertec Industrial Initiative intends to complete feasibility studies with the next three years. Pending a positive outcome of these studies and positive political and financial backing, CSP generation in desert areas looks set to make a significant impact on the energy market of tomorrow. Although pilot installations could start making a contribution at an earlier stage, a large scale contribution to the region's power supply is unlikely to be made for several decades.

In 1992, ABB presented a vision of Europe's future power grid, which was remarkably similar to that which the Desertec Industrial Initiative is now pursuing.

ABB has the know-how and technologies that will permit the company to make a significant contribution to Desertec. Some of these are illustrated in 3. Although the Desertec Industrial Initiative focuses primarily on the EUMENA region, the concept can equally be applied in the world's other desert regions, be they in the Americas, Australia or Asia, and can reduce the world's carbon footprint on a vast and hitherto unimaginable scale.

For more information on Desertec, please visit www.desertec.org.

Andreas Moglestue
ABB Review
Zurich, Switzerland
andreas.moglestue@ch.abb.com

Footnote

6) The study, "Trans-Mediterranean Interconnection for Concentrating Solar Power" was commissioned by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.