Foto: Wikipedia

Image 1: Large solar power stations in the desert regions of the earth (seen here in California/USA) are capable of securing humanity's long-term energy requirements. A solar power parabolic trough system uses cylindrical mirrors to concentrate sunlight onto absorber tubes. The heat created is transferred to a steam plant and generates electricity.

The Future of our Energy Supply

A Scientific Overview

By Michael Düren

Who really wants to sit in the dark, freeze in the winter, and forego modern methods of transportation? Light, heat, refrigeration, machines, and transportation are just a few of the central engineering achievements of our society. All of them are only possible because of the constant availability of something that we call energy. In this article, the subject of our society's energy supply will be explored from the scientific point of view in a clear and simply structured way. This examination will lead to a little known and only superficially abstruse idea: Importing electricity from the deserts of Africa.

The overwhelmingly largest part of the world's energy requirements today is supplied by fossil fuels, that is oil, coal, and gas. These fossil fuels were formed in the geological past by plants and ultimately by sunlight. Besides being limited and non-renewable, all fossil fuels release CO2 during combustion. The resulting increase in CO2 concentration in the atmosphere and the resulting changes to the climate are at the heart of the current energy crisis. The so-called anthropogenic greenhouse effect has been studied intensively for the last 20 years [1], was long-debated and, as a result of the far-reaching consequences for our society was denied. Today, however, its existence is unequivocally recognized in the scientific community [2].

The complexity of the global climate makes quantitative prognoses difficult. However, the size and scope of the possible catastrophic changes due to CO2-emissions is easy to derive. The severity of these changes should not be the focus of our concern, rather we must ensure that no more CO2 is emitted than the atmosphere can handle. Currently, what we consume in oil each day, took a thousand years of geologic time to create. It is now apparent, that this state of affairs cannot continue indefinitely. While there are new ideas to deposit and store the CO2 generated from combustion, no secure large-scale technical plans are on the horizon. Also, this would ultimately only exacerbate the problem of the finiteness of fossil fuels.

Nuclear Energy

Albert Einstein's famous equation E=mc2, expresses that a small mass m is equal to a large amount of energy E. This equivalence explains how a small amount of nuclear fuel can produce large amounts of electricity. Principally this works in two ways: through the fission of large atomic nuclei, like Uranium, Thorium or Plutonium and by fusing smaller atoms like Deuterium and Tritium to Helium. Current research into civil applications for nuclear fusion is on the level of basic research and will require at least another 50 years before large scale commercial applications become available. Therefore, nuclear fusion is not a solution to the current energy problem.

However, nuclear fission has been operated commercially since the 50's and currently produces 25% of German electricity and 7% of global energy requirements. In Germany, after it was decided to phase out nuclear energy, new reactor construction is now being discussed and a 'phasing out' of the 'phasing out'. Still, the discussion of opportunities and risks of nuclear energy splits the society into committed proponents and opponents to this technology. The German Physical Society has just come out against shutting down existing nuclear power stations, so that the goals of CO2 reduction can be realised more quickly [3]. In this case, one can see that climate change is perceived as more threatening than the risks of nuclear energy.

Viewed globally, nuclear energy alone cannot be the solution for the climate problem as 13,000 nuclear reactors would be necessary to replace the energy provided by fossil fuels. Any nuclear reactor can, with minor modifications, be used to produce Plutonium for weapons, and every reactor can be a potential target for a horrific terror at-

Image 2: Nuclear energy plants create large amounts of electricity from small amounts of nuclear fuel (Seen here the Nuclear Power Plant Biblis). 13,000 nuclear reactors would be required to replace the current energy consumption of fossil fuels.

Foto: Kuebi

tack. As discussions about North Korea and Iran have shown, the current political climate is not conducive for a global expansion of nuclear energy from a security perspective.

Saving and Managing Energy

Saving energy and increasing efficiency of energy consumers is one of the most important short-term strategies to reduce CO2 emissions. Several popular examples include: home insulation, the passive solar house, cogeneration, energy saving lamps and the three-litre car. One not so well known, but nonetheless important option is load-management. By intermittently disconnecting consumers, the provider has the opportunity to avoid peak times and therefore has the opportunity to use his power stations and other fluctuating sources like wind-power facilities more efficiently. Technically, this can be done by using modern electricity meters. These can keep track of different tariffs at different times of the day and can switch off specific appliances at peak tariff times. This kind of graded scale has long been familiar in both telephone tariffs and airline prices. For example, the freezer timer would be set so as to not turn itself on during peak tariff times, and washing machines, and dishwashers could be programmed to run when rates are low.

Foto: Florian Baumann

Image 3: Windmill from 1822 from Borsfleth in Schleswig-Holstein and now located in the open-air Museum Hessenpark in Neu-Anspach.

Foto: Hans Hillewaert

Image 4: As the winds are stronger on the open seas than on the land, it makes good sense to set up offshore wind farms despite the higher investments and maintenance costs. Each of the rotors, located off of the Belgian coast has a diameter of 126 m and a capacity of 5 MW.

Renewable energy sources: Biomass, Water, Wind, and Geothermal

Renewable energies are energy sources, that can't be 'used up' or that at least can grow back. The campfire is renewable only as long as the same amount of wood grows as is used. Similarly, pellet heating is renewable only as long as a few people use it. If every German used pellet heating, then in short course all of the forests would be cut down. The combustion of biomass also releases CO2 and can only be referred to as renewable as long as only as much is used as is replanted. It's easy to show why biomass is not a solution to the energy crisis, as huge agricultural areas are required for the production, leading to direct competition with the production of foodstuffs. The amount of corn required to produce one tank of gas is enough to feed one person for a whole year. In the face of starving people on this earth, who would dare drive a car?

Hydropower from dams is an efficient and reliable source of electricity. This type of power generation plays a large role in areas with a great deal of water and mountains like Scandinavia. However, the construction of new dams also has its downsides, and can create a lot of environmental damage. Currently, the hydroelectric potential of many countries is already exploited and can only provide a small contribution to solving the energy crisis. Tidal power, however, may be a different story. Research will show whether in the future tidal, wave and hydrothermal power stations can create large amounts of energy.

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Michael Düren was born in 1957, studied physics at the RWTH in Aachen and wrote his PhD dissertation about the nuclear effects on quarks in the atomic nucleus in an experiment at CERN in Geneva. Thereafter he was at the Max-Planck Institute for Nuclear Physics in Heidelberg and at the University of Erlangen-Nürnberg. In 1996 he received his Habilitation for his work at the HERMES experiment in Hamburg. After an interim professorship in Bayreuth, he was appointed in Giessen. In the framework of large international cooperations at CERN, DESY, and GSI/FAIR he continues his research into the inner structure of the proton. Professor Düren has been a member of the Energy Working Group of the German Physical Society since 1998, and he is involved in exploring social and technological aspects of energy supply and climate change. He is one of the initiators of the interdisciplinary seminar series and a Workshop entitled "Solar Energy Partnership with Africa (SEPA)" at the University of Giessen.

The wind, which has been used as a source of energy since time immemorial for sailboats and windmills, is now experiencing a triumphant return with modern wind farms. Wind farms in good locations are an inexpensive, renewable source of energy. In the interim, 6% of German electricity is created through wind energy. Particularly good locations include coastal areas of the North and Baltic Sea in northern Europe and the trade winds areas, south of Europe e.g. Morocco. Particularly strong winds can be found on the high sea, which makes offshore wind farms profitable. The main problem with wind power is that it varies in capacity. There are three measures that are suitable to compensate for this deficit. Through the inter-connection of wind farms relative fluctuations become smaller. Secondly, power storage facilities can hold the generated electricity, and finally load management can compensate for fluctuations.

Geothermal energy has long been used in geologically active regions of the world for heating and for generating electricity (e.g. in Iceland). Its use in average regions with low geothermal temperature gradients is interesting for creating heat for homes. The potential of generating electricity by using deep drilling technology is currently being intensively examined. However, geothermal energy will likely only play a limited role in solving the energy problem.

Solar power: The bread and the crumbs

Hani el Nokraschy, an Egyptian speaker at the SEPA 2008 workshop (Solar Energy Partnership with Africa) compared the relative potential of solar power with other renewable energy forms as that of a loaf of bread compared to crumbs. The amount of energy that the sun shines onto the deserts of our earth in one day is equal to the global energy consumption in one year. Viewed in this way, there is no energy problem. Even if only a fraction of the solar energy from the deserts were used, we would have energy in abundance.

There are in principle two methods to convert sunlight into electricity. Photovoltaic solar power is an elegant high-tech method. We are all familiar with the black-blue glittering solar panels on German roofs. Photovoltaic production is highly subsidized through a feed-in tariff but despite thousands of private installations, yields no particular contribution to the national grid. Ultimately these subsidies end up with (foreign) solar panel producers, who refuse to offer less expensive models. Photovoltaic cells are also still the subject of basic research. The goal is to develop inexpensive and efficient cells that use little energy and few resources in their production. The prospects of achieving these goals look good for the coming decades.

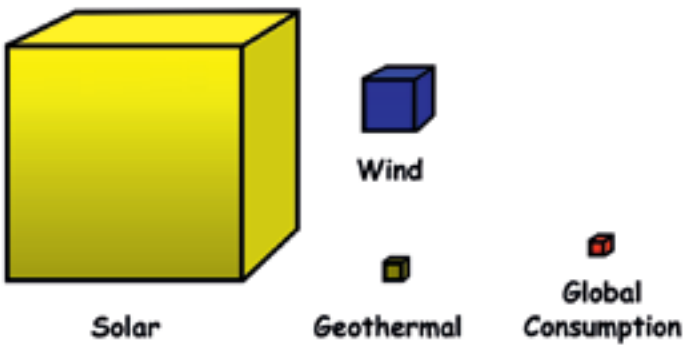

Image 5: The cubes depict the relative sizes of available renewable energy in comparison to the global energy demand. If solar energy were systematically used then an energy crisis would not exist. (Image: Wikipedia)

Foto: JUWI Group

Image 6: In Waldpolenz-Solarpark near Leipzig, the world's largest thin-film photovoltaic facility is being constructed and consists of cadmium-telluride thin film cells.

A somewhat less familiar way to convert sunlight into electricity is by using solar thermal power stations. Using large mirrors, they focus sunlight onto absorbers, which convert the light into heat. Subsequently, the heat is either stored or converted into electricity in a standard thermal power plant. Solar thermal power plants have been built since the 1980's, are reliable and are currently the least expensive form to generate electricity from the sun. The possibility of storing this heat enables a power station to run around the clock.

Electricity from the desert

Modern high voltage direct current (HVDC) electrical power transmission systems are capable of transporting electricity in a large scale, over large distances with low electrical losses. The loss during the transport of solar power from North Africa to Europe is only about 10-15 percent. It is easy to show that an area off less than one percent of the surface of the Sahara, with the help of solar thermal power stations and at-

tendant storage facilities, is sufficient to generate enough energy around the clock for all of Europe [4]. Details of these scenarios can be found in the article about solar thermal power stations in this issue (See article by Daniel Schäfer).

Conclusion:

As a result of the climate change problem our use of fossil fuels will have to be drastically reduced in the coming years. A large, and until now, hardly considered energy potential exists by using solar power stations in the desert regions of the world. This inexhaustible and safe energy source must be harnessed so that it benefits people both in the North and in the solar belt in the South. •

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