Energy in the Future

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Introduction

A strong demand for energy is expected in the future. Estimates for Europe are an increase of energy consumption of 60% until 2050, but much larger increases are expected for the countries in Asia with their immense population and strongly growing industry. The energy production increases with more than 2% per year, in spite of the measures taken by various countries to limit the industrial and private consumption, and the attempts to make motorcars more economical.

In addition to the growing demand, there is the need of replacing existing energy sources and systems of energy production. An important argument is the expected extinction of the oil and gas reserves of the world and the political uncertainty of future delivery by the present oil and gas suppliers. This argument was strengthened by the recent conflicts between Russia and Ukraine that affected the delivery of gas to Eastern and Central European customers. Self-sufficient energy production – a return from globalization – is a goal that gains support from politicians and policy makers all over the world.

A second argument for the replacement of oil and gas as sources of energy stems from the pressure to reduce the CO_2 emissions for climate protection, an argument being accepted by the majority of politicians in the present era. In 1997, at the Kyoto Conference several countries made commitments to stabilize the greenhouse gas emission. In particular, the European Union set values for the reduction of their greenhouse-gas emission at 8% below the value of 1990 by 2012 and 20% by 2020. Inside the European Union a proposal for a worldwide reduction of 80-95% by 2050 is in preparation for the Copenhagen Conference in December 2009, where global agreement should be reached about the future policy.

The arguments favour the development of renewable energy systems like windmills and solar energy devices, but also of nuclear reactors, for which long-term projects are proposed, especially in Russia and the Asian countries. For the short term, the construction of more efficient coal-burning power stations is promoted, with the promise of underground CO_2 storage.

Coal-fuelled power stations

Presently, coal and gas are the largest sources of electricity. Table 1 shows the percentages of the total electricity production provided by coal and gas in the biggest countries of the world.

Table 1		
Region	**Coal (%)**	**Gas (%)**
China	77	10
India	53	10.5
USA	20	49
Russia	23	43

The CO_2 emission of gas is half the coal emission and gas stations are cheaper than coal stations and easier to handle, but up till now natural gas is more expensive than coal which worked in the favour of coal. Presently, governments, electricity suppliers and industries press for new coal-firing power stations to be installed which in first instance will lead to an increase of CO_2 emission.

The installation of coal-fuelled generator stations makes sense from the standpoint of national self-sufficiency: The installations can be created within national borders; pit coal and brown coal (lignite) are generally available, especially in the countries listed above where vast reserves are available.

In the last six years, coal fuelling was worldwide the largest growing market. In Europe which after China and the US is the greatest emitter of CO_2 one speaks about a “coal revival;” 50 new plants will be installed in the coming five years. This year, China which relies more on coal than any other country, overtook the United States as the greatest emitter of greenhouse gases. The demand for energy is large and will increase in the future, so that alternative methods of electricity generation must be developed. However, in the short range these developments will not reduce the extent and the effects of coal burning and it must be foreseen that China, India and other countries will rely on coal-fuelled power for several coming decennia. On the other hand, China is the greatest promoter of low-carbon and carbon-less techniques.

The methods to reduce the CO_2 emission are:

1. Imply regulations on industries for the reduction of their coal consumption.
2. Make coal burning more efficient by improving the burning process. China has many coal-firing power stations where steam turbines are working with an efficiency of 30%. In other countries this efficiency may range between 32 and 36%. By raising the steam temperature beyond the critical point of water to 600 ^{o}C or beyond (SCC), efficiencies of around 45% can be achieved. For China this would result in a reduction of coal consumption of more than 30%. Between 2009 and 2011, China is closing down 30 old coal power stations and installs super-critical stations at a rate of one per month, at a total of 50 GW, 6% of the total Chinese capacity. However, China deploys old-fashioned coal-power stations in parallel, 40% of the total.
3. Gasification of coal before burning (IGCC) is a second step of improvement. Efficiencies of 54% can be achieved and the installations will become more flexible. The gas can be stored and used later or for other purposes or can be liquidized.
4. Storage of CO_2 underground. A considerable reduction of CO_2 emission is anticipated by capturing and storing CO_2 underground in exhausted earth-gas or oil fields or suitable geological formations (CCS). Pilot projects are being conducted at various places in the world and under various conditions. According to expectation, the procedures may reduce the CO_2 emission to the atmosphere by 80 - 90%. Therefore, when applied the global warming would be mitigated. A disadvantage is the high price for capture and storage and the necessary energy consumption which may amount to 25 - 40% (www.ippc.ch) of the net energy output and, consequently, reduces the mitigation. The development meets public resistance because CO_2 storage is not trusted to be effective and the containment underground is questionable. CO_2 storage remains a risky enterprise, since the gas may start escaping from its underground reservoir at any time in the future. In addition, CO_2 stored in continental layers could react e.g. with limestone, resulting in deformation of the earth surface. Storage of CO_2 in the ocean is to be completely rejected because the chemical reaction of CO_2 with water raises the acidity of the sea and endangers the marine biotope; in addition, the confinement is only temporary because of ocean convection. In order to comply with the precautionary principle, one should be very careful with the application of storage methods.

Finally, coal mining is dangerous for the miners (more than 4000 casualties per year in China) and coal burning is dirty anyway. Especially lignite mining is reprehensible because villages and rural areas must be destroyed for the increasing production. The lignite mining and its ecological and social threat is comparable to the oil winning from surface minerals in Canada and the equivalent enterprise as proposed for the Western United States.

Power from coal-power stations is presently advertised as low-carbon energy. In spite of the impressive technical innovations which may become effective in a few decades, CO_2 emission cannot be eliminated. Even if China would reduce the penetration of coal from 77% to 59% in 2030, as envisaged, with a calculated double electricity production by that time, the reduction will be overshadowed.

The continued burning of coal is the greatest concern at the moment. An optimist vision is that the Chinese CO_2 emission will reach its maximum by 2020 and decrease by 60% till 2050; the pessimist expectation is that the Asian emission will increase until mid century.

The demand for coal will rise if it starts replacing motor oil in traffic. In the future, coal may play an important role as a replacement of mineral oil, either by the production of liquid car fuel or by the generation of electricity for electro cars.

At the global climate conference in Copenhagen in December of this year, countries should find an agreement to make new commitments. The general expectation is that it will be very difficult to overcome the reluctance of China and India on one and the US at the other hand.

Nuclear power

The present status of nuclear energy and the prospects for the coming decade are shown in Table 2 which combines data provided by the World Nuclear Association (www.world-nuclear.org/info/reactors.html). The effect of increasing interest and the predominance of Asia in the present development, as mentioned in the introduction are clearly visible. China with only a small number of operating reactors, is leading with over hundred reactors being built or planned before 2030; Europe and the US are cautiously following after a period of some decennia in which they had hardly extended their nuclear capacity.

Table 2

Numbers of nuclear reactors

Country or region	**Operating**	**Under construction**	**Planned till 2017**	**Proposed 2017- 2030**
China	11	12	33	80
India	17	6	10	15
Japan	53	2	13	1
Remaining Asia	29	9	25	37
Russia	31	8	8	28
Europe	165	4	9	57
USA	104	1	11	20
Canada	18	2	3	6
Remaining world	8	1	6	32
Total	436	45	118	276

Energy, since long a geopolitical issue, got new dimensions. For five years the United States and India negotiated about an agreement to open the nuclear market for India. Since India has not signed the Non-Proliferation Treaty (NPT) and is in possession of nuclear weapons, such an agreement violates the NPT rules. The United States administration had political arguments for its nuclear deal, but also hoped to open the Indian nuclear market for doing good business. Ironically, after the Nuclear Supplier Group had lifted the embargo against India by the end of 2008, which actually took away the foundation of their own existence, the way was paved for the competition and Russia was first to jump in with a contract for the delivery of four pressurized-light-water nuclear reactors (VVER-1200) and 2000 tonnes of natural uranium for the Indian heavy-water reactors and an adequate quantity of low-enriched uranium for the light-water reactors. So the prediction of Prime Minister Manmohan Singh came true. At the beginning of the negotiations with the US in 2003, he said in Indian parliament that the deal would open the Indian market for uranium from abroad, and India could reserve its indigenous uranium for its military program.

In Europe, the application of nuclear power changes from country to country. France arduously promoted nuclear energy from the beginning. The electricity generation of the 59 French reactors stands for 76% of the total capacity of the country. The percentage is 13.5 for the United Kingdom, 28 for Germany and 54 for Belgium. In several countries resistance against nuclear energy lead to a government policy that rejected or limited the installation of nuclear reactors. In a number of cases, this rejection was confirmed by legislation. Some countries never allowed reactors to be built (e.g. Denmark), some countries froze their nuclear potential after Chernobyl (e.g. Italy) and some decided to phase out their installations (Germany, Spain, Sweden). In the last years, in all countries a movement came up, urging the governments to change the existing policy and start planning for nuclear energy facilities. Important arguments are the expected extinction of the oil reserves and the political uncertainty of future delivery by the present oil and gas suppliers.

In countries where a moratorium against nuclear energy has been enacted, the laws or policy must be changed if new reactors are to be installed. The most prominent example is Germany, where at the beginning of their term in 2001 the socialist SPD and the Green Party decided to phase out all nineteen nuclear reactors in the country before 2020. Some reactors have been closed already, but after the last elections, the new coalition decided to maintain the existing power plants, but did not take decisions about new reactors. Italy, where the moratorium was the result of a popular referendum, has changed its policy already and the government announced the planning for ten new reactors. Sweden may end its moratorium in the near future. In the United Kingdom the government announced the construction of a new generation of nuclear power plants. Only the Scottish stick to their principle, keeping a nuclear-free Scotland. There are two French reactors under construction in the European Union, one in Finland and one in France.

Considerable development of nuclear equipment, fuels and methods may be expected. New designs of breeder reactors, uranium-233, a reactor fuel converted inside the reactor from thorium and new methods of recycling came up in recent years, developments for a great deal conducted in India. We should not close our eyes for the “nuclear renaissance” which will reshape the picture of nuclear energy and maybe of our future.

Especially when uranium will become scarce and expensive, recycling the reactor fuel after burnout will replace the primitive method of throwing away the fuel as nuclear waste after a single pass through the reactor. A procedure generally followed by e.g. the United States. India worked hard on the so-called closed fuel cycle which would considerably raise the efficiency of natural uranium.

In March 2009, the Russian Rosatom entered a joint venture with Siemens, the biggest technical concern of Europe for the production of nuclear installations. Rosatom will supply reactors on the basis of the VVER technology; Siemens will supply generators, turbines and operating systems and bring in its experience in installation management. Siemens has cancelled its agreement with the French Areva in order to make the new deal. The German-Russian combination expects a market of 400 nuclear reactors before 2030 and intends to become the world market leader. In addition, Russia made an agreement with Japan in May 2009, for delivery of enriched uranium and exchange of technology. There is a European-Asian industrial power developing. There will be big competitors: General Electrics and Areva.

Russia itself plans to increase its nuclear energy potential by a factor four before 2050. This policy is strongly endorsed by Gasprom, the enterprise that controls the Russian natural gas reserves. For Gasprom it is profitable to let the Russian energy market be served by nuclear energy and sell the gas to Europe and China where the prices are much better than in Russia.

How will the world look like, when 400 new nuclear reactors are deployed?

What old and new dangers of nuclear energy can be expected?

- Even if calamities of the Tchernobyl-type will not occur because people have learned from the past, there are new dangers and old ones that will become more acute in the future.
- Reactors will become technically safer, but the increase in number all over the world will cause more accidents. Motorcars and aircraft have shown this phenomenon. Calamities caused by earthquakes, military action etc. can never be excluded.
- General application of a closed fuel cycle will lead to more reprocessing centers. During transportation of radioactive material from the reactor to the reprocessing factory and back – often over large distances – traffic accidents on roads and railways may become disasters.
- The problem of nuclear waste becomes more acute.
- The possibility that fissile material falls into wrong hands is a serious danger. If the number of nuclear reactors in the world increases, especially the number of breeder reactors, much more fissile material, plutonium and uranium-233 will be produced. If reactors become cheaper and smaller, nuclear installations may be installed in localities outside the guarded centers and not under the control of accredited authorities. In that situation, it will become easier for sub-national groups and military factions to lay their hand on fissile material, either by theft or robbery, or by corruption of the controlling organization. Thorium is a new concern: the isotope U233 is equally usable for the production of nuclear weapons.
- Nuclear power was originally a military invention from which a civil side application was derived. Now, the production of nuclear weapons may profit from developments that provide fissile material easier and in greater quantity, and may become accessible for newcomers in the community of nuclear weapon states. The abolition movement should be aware of the technical scenarios in a rapidly changing world. The dilemma is clear: It is generally felt, that the Non-Proliferation Treaty must be saved, since in Article VI it contains the only promise of the Nuclear Weapon States to finally reduce their stocks to zero. But saving the NPT is only possible with the support of all nations who signed the NPT and whom the NPT – in Article IV – promises the inalienable right to civil nuclear energy.

Renewable energy

The recognition of the climate problem by the policy makers gave uplift to the promotion of renewable energy. In 2008, the worldwide investments in renewables were more than half of the total investments in energy production. In March 2007 European leaders signed up for a binding EU-wide target to obtain 20 per cent of their energy needs from renewables such as biomass, hydro, wind and solar power by 2020. On 23 January 2008, the Commission put forward differentiated targets for each EU Member State, based on the per capita GDP of each country. Worldwide, eighteen percent of the produced electricity is renewable; this percentage will go up if the present projects can be realized. Renewable power sources are hydroelectric, bio-fuel, wind, photovoltaic, solar thermal, geothermal and some lesser sources. The future will show us a variety of energy sources and production methods, conventional and new ones and an increasing scale of exploitation. In recent years, Germany was leading in renewable energy, but China is taking over the lead.

There is a lot of popular opposition against nuclear energy, burning coal, brown coal mining and CO_2 storage, but also against wind turbines and bio-fuels. It is necessary to make a risk analysis for all the dangers and hazards that can be expected.

Hydroelectric power

The most important contribution to renewable power production is hydropower with 83% of the total. The largest hydropower plant in the world is the 22.7 GW Three Gorges Dam in China (see Fig. 1). China is the leading country in renewable energy and in hydropower and intends to bring its present capacity of 147 GW to 300 GW by 2020. The future of hydropower is limited by the availability of suitable rivers. Table 3 shows the hydroelectric capacities which are presently installed in various regions of the world.

Hydropower has serious implications for the human community and is dangerous. For the establishment of storage reservoirs, human displacement over large areas may be necessary: For the Three Gorges Dam in China, which is being completed in 2009, cities and villages had to disappear and 1.2 million people had to be displaced. In addition, the disruption of environment and ecosystem is considerable. Once in operation, the storage reservoir is a continuous threat for the people below. When as a result of horrendous rainfall in 1975 the Banqiao Dam in China collapsed, 230,000 people were killed. Hydro installations are the most dangerous tools for producing energy.

Fig. 1
Three Gorges Dam

Table 3
Hydroelectricity installations

Region	GW
Europe	226
China	147
Brazil	82
United States	78
Canada	72
Russia	38
India	37
World total	848

Bio-fuel

Bio-fuel consists in different varieties. Household refuse and waste from forestry and wood-processing industries can be burnt in conventional power plants or been gasified for the generation of electricity. On the other hand, sugar-weed is cultivated in tropical areas to produce alcohol as a fuel for motorcars. We must object to this culture, since it withdraws agricultural land from traditional farming and results in the destruction of tropical forests. It endangers the food production in poor countries of the South. A revival of colonialism is on hand, where poor and hungry people work on the plantations to fill our motorcar tanks with spirit. In addition, bio-fuel cultivation needs large farming areas which have a very low energy yield, compared e.g. with an equal area covered with solar panels. This in particular, is true for fuel produced from e.g. maize and rape, where transportation and preparation of the product consumes most of the produced energy.

Fig. 2
Jatropha curcas plantation

Table 4

Country	Wind energy (GW)	Total energy (GW)	(%)	Target 2020 (GW)
USA	25.2	995.0	2.5	?
Germany	23.9	137.5	17.4	55
Spain	16.7	95.0	17.6	40
China	12.2	793.0	1.5	100
India	9.6	147.4	6.5	20 (2012)
World total	**121.2**	**4033**	**3.0**	

Another bio-fuel is diesel oil that can be produced from the seeds of the Jatropha curcas shrub which grows in Asian countries (see Fig.2). It is said that Jatropha can grow on bare and dry soils, unusable for agriculture or anything else. India intends to plant 1,400 km^2 of Jatropha forest which should produce 20% of the national consumption of diesel oil. In China, 6,700 km^2 of Jatropha forest should produce 1.26 Gigaliter of biodiesel per year. Of course, there must be people to harvest the seeds, but the car drivers will be happy.

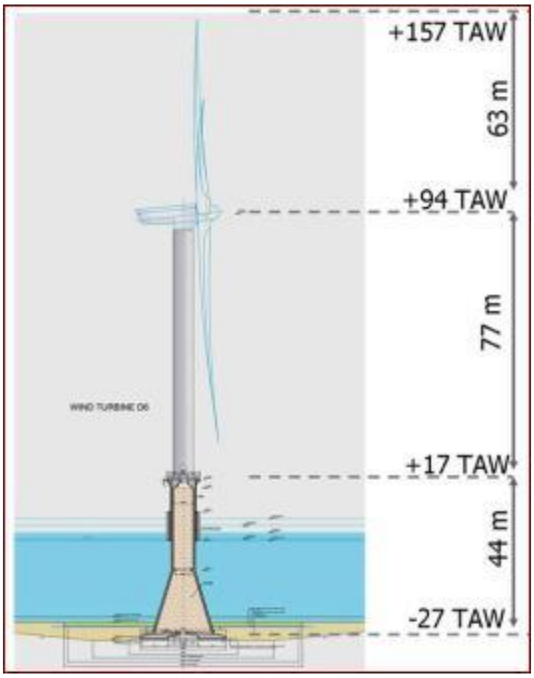


Fig. 3
5 MW offshore wind turbine (top), concrete foundations (bottom).
Zeebrugge Belgium

Wind power

The production and deployment of wind turbines became an expanding market in the last years. Table 4 shows the present capacity in different countries and the targets set for 2020.

The present data all refer to land based turbines, however, the target data include offshore installations. In Europe several countries around the North and Baltic Sea installed offshore wind farms or experimental turbines (see Fig. 3). In the coming decennia, a large expansion of wind farms along the coasts of the North and Mediterranean Sea, along the Chinese coast and the Atlantic coast of the US is to be expected. Offshore implementation is preferred because of the better wind conditions at sea and the absence of most limitations and barriers and the popular resistance that prevail on the mainland.

How will the North Sea look with 20,000 wind turbines (100 GW), and what consequences will there be for the ecosystem, the environment and the marine traffic?

Photovoltaics

With the present technology, solar cells have a low capacity and therefore need large areas to become effective. Moreover, they are expensive. Since they do not produce electricity at night, their capacity factor is low. To save space, installation on roofs of buildings is an appropriate solution. The City of Osnabrück made the calculation that 70% of its

Fig. 4
Solar panel array, 21,000 m^2
Madrid

electricity consumption could be supplied by solar cells, mounted on all suitable roofs.

Solar cells may be used stand alone in local areas, in which case storage on accumulators is necessary to supply electricity also at night. In this case, only direct current is available. Solar cells can also be connected to a general electricity grid by a direct current/alternating current converter in which case alternating current is available twenty-four hours a day.

Solar cells can also be installed in deserts where the sun shines regularly and space is available. In this case it is profitable to mount the cells on panels that can be turned into the direction of the sun and be kept in that direction by continuous adjustment.

Technical progress can make monocrystal-silicon cells less expensive; much work is done on the development of new materials.

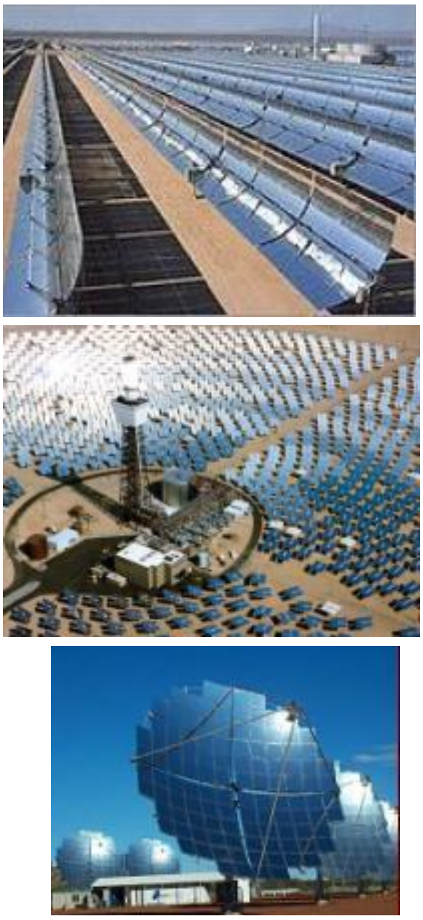
Thermal solar power

Steam or air can be heated directly by sunlight which is focused on a pipe or kettle by mirrors. Installations are in operation in sunny areas: USA (California), Spain, India (Rajasthan), China, Australia. For the reflection of the sunlight there are different options:

Fig. 5a The trough solution; line focus. A long parabolic cylinder is placed in east-west direction. It reflects the sun to a pipe mounted in its focus axis, if the mirror is continuously rotated around its axis in order to follow the movement of the sun. In the pipe a liquid is heated which evaporates water and produces hot steam.

Fig. 5b A set of mirrors reflects the sun to a boiler which is on the top of a tower; point focus. The mirrors must be individually adjusted around two axes to track the sun. Steam from the boiler drives the turbine.

Fig. 5c There are large parabolic mirrors with a Stirling motor in their focal point. Again, the mirror is continuously adjusted to the position of the sun.



5a

5b

5c

Fig. 5
Thermal solar power devices

The thermal solar solution allows for storage of heat in molten salt during the sun hours. At night, the salt is used for producing steam that powers the same turbines as during the day. This method is considerably simpler than equivalent methods for storage of wind and photovoltaic energy.

Renewable power proposals

In 2003, the Club of Rome founded the Trans-mediterranean Renewable Energy Collaboration (TREC), proposing to supply energy for the EUropean, Middle-East and Northern African (EUMENA) regions, making use of the sunshine in the Sahara desert.

For the transportation of electricity from Africa through the Mediterranean Sea to Europe, High Voltage Direct Current cables (HVDC) can be used. These cables are laid underground or under the bottom of the sea and have very low losses compared with conventional alternating current cables.

In 2009, twelve industrial and financial institutions and electricity providers came together to establish the DESERTEC Industrial Initiative (DII). Among the industrial companies are ABB, the inventors of the HVDC cable, financial institutions like Deutsche Bank, HSN Nordbank, Munich RE, electricity providers E.ON and RWE and finally Siemens, not only interested in nuclear reactors, but being a leading provider of HVDC cables, steam, water and wind turbines, in particular the big off-shore turbines deployed at the moment. The proposal is to install concentrated solar power plants in the Sahara and combine them with wind turbines and other renewable-power stations (see Fig. 6). It is estimated that with an investment of 400 billion €, 100 GW power can be obtained by 2050.

Fig. 6

The DESERTEC proposal

The proposal is not in harmony with the principle of self-sufficiency as mentioned at the beginning of this lecture; it includes a great political uncertainty. Solving this geopolitical problem is a crucial condition for the success of the enterprise.

Comparison

In Table 5 the energy output of a hydropower installation is compared with a nuclear reactor and various existing types of wind turbines and solar power devices. The capacity is the nominal power of the installation under optimal operation. The actual power is reduced by insufficient water supply for the hydro installation and by the irregularity and intermittence of the wind velocity for the turbines. This reduction is expressed by the capacity factor.

Also the solar heat devices are subject to this factor, since they do not work at night and have a varying opening to the sun during the day. The table shows the relatively low capacity factor for land based windmills and the better conditions at sea. Remarkable is the high capacity factor of the nuclear reactor which only deviates from 100% by maintenance and repair.

The energy output is quoted in Terawatt hours per year and is obtained by multiplying the capacity with the capacity factor and 8640, the number of hours in a year. Whereas six nuclear reactors have an output, equivalent to the hydropower installation, great numbers of wind turbines are needed to obtain

Table 5

Installation	Capacity (MWe)	Capacity factor (%)	Number of installations	Energy output (TWh/y)	Price 2008 (G€)
Hydropower Three Gorges Dam	22.600	37	1	72.2	?
Nuclear reactor EPR 1 / 2	1,600	90	6	74.6	32 / 24
Windmill onshore Average USA	1.65	24	21,100	72.2	41
Windmill onshore Average Germany	1.2	19.5	35,708	72.2	43
Windmill offshore Lillegrund, Sweden	2.3	35	10,380	72.2	?
Windmill offshore Belwind, Belgium	6	42	3,316	72.2	48
Concentrated solar PS10 Sevilla	11	26	2,922	72.2	103
Trough solar power Nevada Solar One	64	24	538	72.2	97

the same result. Because of the effect of wind shadow, turbines cannot be located too close to each other and therefore wind farms cover a considerable area. This fact leads to the resistance of part of the public against wind energy. But if DESERTEC reaches its goal, many thousands of wind turbines will populate the European seas.

The quoted prices in the last column only refer to the installation of the items, not to maintenance cost or fuel for the reactors. The price of the installations increases downward the table. It is clear that offshore turbines are more expensive than onshore units. In addition, the maintenance will be more expensive at sea. The price difference is diminished by the higher capacity factor at sea. For land based turbines not enough space is available to reach considerable capacity. The solar heat installations again are more expensive, still less expensive than photo cells. The proponents of solar power believe that the price will come down by mass production and cheaper materials and will become comparable with the price of conventional installations.

IRENA

In January 2009, seventy-seven states founded the International Renewable Energy Agency (IRENA) in Bonn, Germany. The membership rose to more than eighty in between. Since India is one of the members, the organization spans one third of humankind. The task of the agency will be to “promote renewable energy all over the world and advice people and countries how to handle it.” IRENA compares itself with the International Energy Agency and the International Atomic Energy Agency, but does not strive for the status of a United Nations organization. It should be independent and only consist of members that support the principles of the agency.

Desalination

Clean water is an equally acute problem as energy. The freshwater sources of the tropical and subtropical regions of the earth are totally insufficient for the growing population. Desalination of seawater (e.g. distillation) is already being practiced with installations that use e.g. oil as a fuel. The solar-heat power plants can produce fresh water by distillation of sea water as a sideline of their electricity generation, or separate solar-heat installations can be established.

There is an alternative scenario which is much less attractive. In China and in South-Africa nuclear reactors are under development that can be dedicated to desalination. These so-called pebble-bed reactors consist of a container in which a large number of pebbles – graphite balls of the size of a tennis ball – are stored in which the reactor fuel is dispersed. The pebbles are continuously taken out for inspection and replaced or rejected if necessary. A 200 MW prototype with 360,000 pebbles will be in operation by 2010 at Tsinghua University in Beijing. The manufacturers intend to produce 20 reactors for desalination before 2020. A similar project in Koeberg, South Africa is to produce 10 desalination reactors for use in South Africa and 20 per year for export.

The reactors are helium cooled and have a negative temperature coefficient, so that explosions of the Tchernobyl type are excluded. However, they can easily be used for the production of weapon-grade material by putting in pebbles of depleted uranium or thorium. Installation of these reactors at remote points along the coast, possibly in politically unstable areas would be a permanent risk. A risk that can be avoided by solar-power installations in sufficient numbers.

Conclusions

- Energy production will make use of a mixture of techniques and sources;
- Coal burning will still be applied for decennia; the greatest concern;
- Nuclear power will expand;
- Renewable power will expand, especially solar-heat and wind power.

Evolution of thinking:

1. CO_2 danger and renewable energy started in the minds of unworldly scientists and environment activists.
   It would harm our economy, even endanger our national values!
2. Politicians and decision makers become gradually and reluctantly convinced.
   The danger seems real, let’s do something.
3. The industry takes over.
   It is good business and creates jobs, let the government invest money!
   And it is good for the climate!