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# Energy & climate♣

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Based on published reports a short survey is presented on climatic change. Considering world's increase in temperature the use of fossil energy should be replaced as far and as quickly as possible by alternatives. Actual methods for energy production are discussed. At present, only nuclear power plants and concentrating solar power plants are able to meet the large requirements. Regarding the limited resources of nuclear fuel, costs and problems of nuclear techniques urgently solar techniques should be developed for an extended application.

## 1. THE SITUATION

Today's societies are extremely hungry for energy. In ancient times biomass was used. Wood was both: building material and energy source. Fortunately humans found coal before inventing steam engines. Otherwise on earth trees hardly had been survived. Nowadays we use exhaustively fossil resources. Since the 1960th we have an intensive energy debate [1].

- It was anticipated that due to increasing consumption the resources of fossil energy could be exhausted within few years. – In fact, we have coal for at least 200 years and oil and gas for more than 50 years. Continuously new oil,

♣ Dedicated to Professor Emil Chibowski on the occasion of his 65th birthday.

gas and coal deposits are explored; still more is detected than actually used. Furthermore, we have enough alternative sources. E.g. the sun provides thousand times more energy as used today. But until now, exploiting fossil deposits is much cheaper than conversion of solar energy.

- After the disaster of Tschernobyl in 1986 nuclear accidents were feared. The people of some few countries decided to abstain from nuclear power. In fact, coal mining, transport and processing involve much more deadly accidents than nuclear power production.
- Now it becomes clear that we are going to change our climate as a consequence of burning fossil material [2-4]. Release of carbon dioxide into the atmosphere leads to a moderate increase in temperature. Temperature increase of some few centigrade causes no catastrophe, neither for the earth, nor for life [5, 6]. In the contrary: higher temperatures will favour life and its further development. It is better for human beings because the thermodynamical equilibrium temperature is about 27 °C. That is just the temperature produced by natural burning processes at body's surface. To hold that temperature in our climate region we need clothes. The northern hemisphere containing the largest part of country may profit [7]. Possibly Greenland will become habitable. Arctic Ocean routes will be opened.

On the other hand, there are earnest reasons to stop exploitation of fossil deposits and misuse of our atmosphere:

- It is an ethic position not to waste resources in some few centuries which originate from millions of year's formation.
- By excessive exploitation of wood as a home and shipbuilding material and energy source the Mediterranean countries had been ravaged. Jared Diamond pointed out in his book "*Guns, Germs, and Steel – The Fate of Human Societies"* [8, 9] that destroying of natural resources as clear cutting of forests and misuse of soils can cause the collapse of a society.
- We learned that by influencing the atmosphere strong variations of the conditions on Earth may occur. Thus, it is careless contaminating of the atmosphere.
- Melting of the arctic ice cup and of glaciers is already occurring [10, 11]. Melting of ice is faster than expected, because ice is not a compact crystal. In fissures we find supercooled water with temperatures down to -50 °C [12]
- Increase of the sea level will submerge some islands and coastal regions.
- Increasing aridity in equatorial zones and forest fire due to dryness in temperate zones will occur.

- More violent storms are expected as a consequence of abundant weather variations.
- Immigration of vermin and of tropical diseases from southern countries are observed already.
- Thawing of permafrost soils will cause sinking of buildings, constructions, rails into the marshy ground.
- In southern regions for several plants and animals a loss of living space will occur. An enormous migration of people may result.

1992 during a United Nations framework convention at Rio de Janeiro yearly conferences (Conference of the Parties, COP) had been scheduled in order to find measures to reduce the climate change. Later on those very large conferences had been complemented by meetings (Meeting of the Parties, MOP, CMP) in order to make its work more effective. Table 1 gives a survey on the most important UN COP's, MOP's and a meeting of the group of the 8 nations.

Tab. 1. Selected United Nations conferences on climate change.

| Meeting | Date | Place |
|---|---|---|
| United Nations Framework Convention on Climate Change | 1992 | Rio de Janeiro |
| COP1 | 28.03.–07.04.1995 | Berlin |
| COP3 | 01.12.–10.12.1997 | Kyoto |
| COP6 | 13.11.–24.11.2000<br>16.07.–27.07.2001 | Den Haag<br>Bonn |
| COP7 | 29.10.–09.11.2001 | Marrakech |
| COP9 | 01.12.–12.12.2003 | Milano |
| COP10 | 06.12.–17.12.2004 | Buenos Aires |
| COP11 / MOP1 | 28.11.–09.12.2005 | Montreal |
| COP12 / MOP2 | 06.11.–17.11.2006 | Nairobi |
| G8 Meeting | 06.07–08.07.2007 | Heiligendamm |
| COP13 / MOP3 | 03.12.–14.12.2007 | Bali |

In the following we will try to give a short and realistic survey based on published surveys. This is not easy because on the one hand the item is somewhat emotional. On the other hand the energy market and likewise measures to reduce climatic change concerns much money. Many of reports are sponsored from interested parties. Nicholas Stern [13] assessed expenditures of 300 billion $ arsing from consequences of world temperature increase. He calculated that it would be much cheaper to limit that increase. Realistic assessments are made by the insurance and reinsurance companies which are concerned with big property damages. Such companies reckon with increasing damages due to storm, hail, inundation and aridity due to increasing weather instabilities. However, they believe that most of such occurrences should be insurable.

## 2. THE TEMPERATURE OF THE EARTH

The mean surface temperature of the Earth is determined by solar radiation and reflux of heat radiation from the Earth (Table 2). Heat release from the interior of the Earth produced by radioactive processes can be neglected [14]. The Earth receives energy from the Sun in the form of electromagnetic radiation. Solar radiation is radiant energy emitted by the sun which is a nuclear fusion reaction that creates electromagnetic energy. The radiation comes from an about 200 km deep zone of the outer region of the sun. The spectrum of solar radiation is close to that of a black body of the temperature of about 5800 K. About half of the radiation is in the visible short-wave part of the electromagnetic spectrum. The other half is mostly in the near-infrared part, with some in the ultraviolet part of the spectrum. The radiation power amounts to 3.86 x $10^{20}$ MW and because of the near distance all other radiation sources of the universe can be neglected. The solar constant s = 1.37 kW / m² describes the solar radiation that falls on an area above the atmosphere at a vertical angle. The maximum of the energy distribution is in the range of 450–480 nm wavelengths. The Earth reflects about 30 % of the incident solar flux (Albedo); the remaining 70 % is absorbed, warming the land, atmosphere and oceans. In the mean that influx amounts to 0.344 kW $m^{-2}$. To the extent that the Earth is in a steady state, the energy stored in the atmosphere and ocean does not change in time, so energy equal to the absorbed solar radiation must be radiated back to space. Earth radiates energy into space as black-body radiation, which maintains a thermal equilibrium. This thermal, infrared radiation with wavelength between 3 and 50 μm increases with increasing temperature. One can think of the Earth's temperature as being determined by the infrared flux needed to balance the absorbed solar flux. Indeed the effect is more complicated because selectivity of the gas molecules and of clouds to radiation, and in addition convection must be regarded for quantitative assessments.

Tab. 2. Selected figures of sun and earth.

| | |
|---|---|
| Sun | |
| Temperature | 5 800 K |
| Radiation power | 3.86 x 1020 MW |
| Solar constant | 1.37 kW $m^{-2}$ |
| Maximum of energy distribution | 450–480 nm |
| | |
| Earth | |
| Reflectance | 30 % |
| Influx | 0.344 kW $m^{-2}$ |
| Maximum of energy distribution | 3–50 µm |
| Greenhouse effect | 20–30 K |

## 3. THE GREENHOUSE EFFECT

The greenhouse effect (GE) [15, 16], discovered by Joseph Fourier [17] in 1829 and first investigated quantitatively by Svante Arrhenius [18] in 1896, is the process in which the emission of infrared radiation by the atmosphere warms a planet's surface. The Earth's average surface temperature is about 20-30°C warmer than it would be without the greenhouse effect The visible solar radiation heats the surface, not the atmosphere, whereas most of the infrared radiation escaping to space is emitted from the upper atmosphere, not the surface. The infrared photons emitted by the surface are mostly absorbed by the atmosphere and do not escape directly to space. Several atmospheric gases are transparent for visible light from sun but absorb infrared radiation from Earth surface. Such gases are listed in Table 3. In contrast dust particles reflect light and therefore when closing East German’s heavy industry and some dirty power plants a temperature increasing effect was measured.

GE may be defined to be the difference between the infrared radiation that the surface would radiate to space if there were no atmosphere and the actual infrared radiation escaping to space (Table 3). Then compute the percentage reduction in GE when a constituent is removed [19]. By this particular measure, water vapor can be thought of as providing 36% of the greenhouse effect, and carbon dioxide 9%, but the effect of removal of both of these constituents will be greater than the total that each reduces the effect, in this case more than 45%.

Tab. 3. Atmospheric contents affecting climate. * indicate contaminating gases which should be reduced at about 5,2 % in comparison to 1990 in accordance to the Kyoto protocol. GE = Greenhouse effect.

| | | GE % | |
|---|---|---|---|
| Water vapour, clouds | $H_2O$ | 36 | |
| Carbon dioxide | $CO_2$ | 9 | * |
| Methane | $CH_4$ | 20 | * |
| Ozone | $O_3$ | 3 | |
| Nitrogen oxide | $N_2O$ | | * |
| Partially halogenated Fluorohydrocarbons | (HCFC) | | * |
| Perfluorohydrocarbons | (HFC) | | * |
| Sulphurhexafluoride | $SF_6$ | | * |
| Dust particles | | | |

## 4. ENERGY CONSUMPTION

Luxurious life in ancient times was enabled by slaves and by combustion of biomass. Today, slaves have been replaced widely by engines operated with energy and by materials produced by energy consume. Since the advent of the industrial revolution, the worldwide energy consumption has been growing steadily. In 1890 the consumption of fossil fuels roughly equalled the amount of biomass fuel burned by households and industry. In 1900, global energy consumption equalled 0.7 TW = 0.7 x $10^{12}$ W. In 2004, the worldwide energy consumption of the human race was on average 15 TW = 15 x $10^{12}$ W with 86.5 % from burning fossil fuels [20]. This is equivalent to 0.471 ZJ = 0.471 x $10^{21}$ J per year. Table 4 presents the energy consumption in 2006. About 1/3 of energy is used by industry, 1/3 of traffic, equally industry, trade and private and 1/3 is consumed by private households.

Tab. 4. Energy consumption 2006.

| Fuel type | Power<br>TW = $10^{12}$ W | Energy/year<br>EJ = $10^{18}$ J |
|---|---|---|
| Oil | 5.6 | 180 |
| Gas | 3.5 | 110 |
| Coal | 3.8 | 120 |
| Hydroelectric | 0.9 | 30 |
| Nuclear | 0.9 | 30 |
| Geothermal, wind, solar, wood | 0.13 | 4 |
| Total | 15 | 500 |

## 5. ENERGY SOURCES

We distinguish between different types of energy:

- Primary energy is all what we find as natural energy source
- Secondary energies are types of energy made from primary energy but which can be easily stored or transported. That is in particular electricity but also hydrogen, water pumped in reservoirs and mechanical energy. For heat storage reservoirs of water or molten salt are used.

Without loss only primary energy can be used directly, in particular for heating. Transformation into secondary energy always is accompanied by major loss. In heat power plants about half is lost on account of the second law of thermodynamics. Reason is that in heat power machines only a part of heat energy can be transformed into mechanical energy whereas another part goes into heat of low temperature which mostly is destroyed within the large cooling towers we can see everywhere near power plants.It is the charm of combined heating power stations that waste heat of power production is used. However, such small facilities within residential areas are not very reasonable, neither economically nor ecologically. They need both, decentralised coal and electricity transport and they produce carbon dioxide.

The remaining worldwide energy resources are large (Table 5), with fossil fuels totalling an estimated 0.4 YJ = 0.4 x $10^{24}$ J [20]. However regarding assessments of previous years such figures should be valuated as highly speculative. A lead time of decades of years is required for prospecting and exploitation in particular for nuclear fuel which is found in low concentration only.

Tab. 5. Energy resources estimate.

| Fuel | Energy reserves ZJ = $10^{21}$ J |
|---|---|
| Coal | 290 |
| Oil | 19 |
| Gas | 16 |
| Nuclear | 2500 |

Mostly thanks to the sun, the world also has a renewable usable energy flux that exceeds 120 PW = 120 x $10^{15}$ W.

## 6. COAL, OIL AND GAS

Coal fuelled the industrial revolution in the 18th and 19th century. With the advent of the automobile, airplanes and the spreading use of electricity, oil became the dominant fuel during the twentieth century. Over the last forty years, the use of fossil fuels has continued to grow and their share of the energy supply has increased. In the last three years coal has reclaimed its legacy as the fastest growing fossil fuel. 45 coal fired power stations are in construction in Germany and in China each weak one is connected to the network. Coal reserves are expected for about 200 years, oil and gas for 50 and 80 years, respectively. In comparison to investments in electricity, coal, gas and oil, those in alternatives are negligible.

Coal is nearly completely carbon and that is oxidised 100 % to $CO_2$. Oil is a little bit better because consisting of hydrocarbons which partially produce water. Natural gas contains more hydrogen. Coal processing causes comparatively most of deadly accidents because on dangerous mining and the high amount of transport. Furthermore, a coal power plant releases radioactive $^{14}C$. Of course, that is a natural component of the air. It is proposed pressing of $CO_2$ into emptied gas and oil reservoirs. That is a well known technology for storing helium, which is a component of natural gas. It is doubtful whether this costly and energy consuming process is reasonable for storing waste $CO_2$. Storing of $CO_2$ in the deep sea is fantasy.

## 7. NUCLEAR POWER

Since 50 years, when we are aware of energy problems only nuclear power has been established as an alternative. Besides Uranium also Thorium may be used. However thorium reactors will not play a significant role within the next 25 years because of the long lead time for their development. As of 2004, nuclear power provided 6.5% of the world's energy and 15.7% of the world's electricity. As of 2007, the IAEA reported there are 439 nuclear power reactors in operation in the world, operating in 31 countries [21]. The United States produces the most nuclear energy, with nuclear power providing 20% of the electricity it consumes, while France produces the highest percentage of its electrical energy from nuclear reactors—80 %. In the European Union as a whole, nuclear energy provides 30% of the electricity. Resources which may be exploited economically are assessed for Uranium of more than 60 years and together with thorium for more than 130 years [22].

In breeding reactors nuclear fuel can be produced. Furthermore Plutonium is produced which provides remarkable healthy risks. There had been many incidents in breeding reactors, mostly based on leakages on account of high temperatures and burning of sodium which is used as a coolant. Until now Uranium is cheaper than artificial nuclear fuel also no breeder is working safely. Because of the long lead times for its development and market penetration nuclear breeding reactors will not play a significant role within the next 25 years.

Emission of radioactivity in nuclear power plants usually is below the detection limit. In contrast, radioactive carbon $^{14}C$ is released when burning carbon. Nuclear power plants are very clean and have an extremely high standard of safety. The risk of a serious nuclear accident therefore is low. However, damage costs like those of Tschernobyl (Ukraine) are extremely high; therefore nuclear power plants are not insurable. The most serious nuclear accident was in Kytschtym (Russia). That research plant, however, was engaged mainly with military use of nuclear techniques.

The costs of decommissioning the nuclear power station after about 40 years of operation were found recently in Great Britain to be 6 b$ for a 1000 MW Power station [23]. Projected to the commissioning time this amounts to about 1500 b$ that has to be added to the construction costs of 2–2.5 b$ (but usually neglected). Drawback of nuclear techniques is the long-range storage of waste required and since 50 years operation that problem is not yet solved. Until now that was not a problem because there is comparably little waste.

Fusion power is what powers our sun. It generates large quantities of heat by fusing the nuclei of hydrogen isotopes. The heat can theoretically be harnessed to generate electricity. The temperatures and pressures needed to sustain fusion make it a very difficult process to control and doing so is an unsolved technical challenge. The tantalizing potential of fusion is its theoretical ability to supply vast quantities of energy, with relatively little pollution. Both the United States and the European Union are supporting fusion-based research which may have a practical result in about 50 years. The estimated costs of an operating reactor in 2050 – if it operates – are 12 ct/kWh which is far more costly than most renewable energies.

## 8. HYDROELECTRICITY

Worldwide hydroelectricity power reached 816 GW in 2005, about 15 %, consisting of 750 GW of large plants, and 66 GW of small hydro installations. Large hydro capacity totalling 10,9 GW was added by China, Brazil and India during the year, but there was a much faster growth (8%) in small hydro, with 5 GW added, mostly in China where some 58 % of the world's small hydro plants are now located. In the western world although Canada is the largest producer of hydroelectricity in the world; in Europe there are few possibilities for new plants. The construction of large hydro plants has stagnated due to environmental concerns. Large reservoirs will influence even the Earth motion. When filling first a new reservoir large amount of $CO_2$ are set free. The artificial lake of the Balbina plant in northern Brazil releases up to 2008 about eight times the amount of carbon dioxide and methane as a coal plant of comparable size.

Hydroelectric power plants with high reservoirs in mountains are used as pump storage power stations. Only few electricity is required to pump water into the high reservoir which than can be used to drive turbines if more electricity is demanded, the recovery is about 70%. The capacity of such storage plants, however, is insufficient if fluctuating suppliers (photovoltaic, wind) provide energy in a large scale.

At the end of 2005, 0.3 GW of electricity was produced by tidal power. Thanks to the gravitational pull of the moon (68%) and the sun (32%) there is 3 TW of tidal energy available of which approximately 1 percent is practical to exploit. The best site for capturing tidal energy is the much studied Bay of Fundy on the eastern border of the US and Canada. North America's only tidal power station is a 20 MW demonstration unit at the mouth of the Annapolis River in Nova Scotia.

Waves are derived from wind and wind is derived from solar energy, at each conversion there is approximately two orders drop in available energy. The energy in waves that wash against our shores adds up to 3 TW. So any wave powered system has to be well sited and cost effective since there is not that much energy to capture.

## 9. BIOMASS

Until the end of the nineteenth century biomass was the predominant fuel. Today it has only a small share of the overall energy supply. Each year 200 billions of biomass grows, but only 5 % are used by us. Energy content is in the mean $1.5\ 10^9$ J $m^{-3}$ = 1.5 Gigajoule/$m^3$ whereas fuel has about 35 Gigajoule/$m^3$. A big problem is the water content of plants which must be removed using energy and the large volumes to be transported. Therefore its use in general restricted to nearby users [24]. Electricity produced from biomass sources was estimated at 44 GW in the world for 2005. World production of bioethanol increased by 8% in 2005 to reach 3.3 billion litres, with most of the increase in the United States, bringing it to the levels of consumption in Brazil. Biodiesel increased by 85% to 3.9 billion litres, making it the fastest growing renewable energy source in 2005. Over 50% is produced in Germany. On account of impurities biofuel is not neutral for the climate and recently some concern was raised about its potential to cause cancer.

The use of solar energy via production of biomass indeed is very odd: The process is very time consuming, needs large areas and a lot of undesired by-products are generated. Whereas the use of biomass waste for energy production may be reasonable both ecologically and economically its production for that purpose in concurrence to food production is problematic. Replacing natural forest in order to cultivate fast growing energy plants is irresponsible.

## 10. WIND POWER

The available wind energy estimates range from 300 TW to 370 TW. Using the lower estimate, just 5% of the available wind energy would supply the current worldwide energy needs. Most of this wind energy is available over the open ocean. The oceans cover 71% of the planet and wind tends to blow stronger over open water because there are fewer obstructions. The installed capacity of wind power increased by 25.6 % in from the end of 2005 to end of 2006 to total 74 GW with over half the increase in the United States, Germany, India and Spain. Doubling of capacity took about three and half years. The total installed capacity is approximately three times that of the actual average power produced as the nominal capacity represents peak output; actual capacity is generally from 25-40 % of the nominal capacity. Problem is the need of large areas. To replace a nuclear power plant some thousands of wind wheels are required.

## 11. GEOTHERMAL

Geothermal energy is used commercially in over 70 countries. By the end of 2005 worldwide use for electricity had reached 9.3 GW, with an additional 28 GW used directly for heating. If heat recovered by ground source heat pumps is included, the non-electric use of geothermal energy is estimated at more than 100 GW. Heat pumps do not use geothermal energy but solar energy of near surface layers.

## 12. PHOTOVOLTAIC

Solar photovoltaics provided about 0.1 % of the world's Total Primary Energy Supply (TPES) by the end of 2007. According to preliminary data, cumulative global production was 12.4 GW megawatts. Germany is now the world's largest consumer of photovoltaic electricity, followed by Japan. Drawbacks of photovoltaic are high price and the low efficiency and therefore need of large areas. An advantage of PV is that it works with diffuse light i.e. will give electricity – at a lower level – even when the sky is cloudy.

## 13. LOW TEMPERATURE SOLAR WATER HEATING

This classifies the use of direct sun rays without concentration for heating purposes, mainly heating water, to a temperature lower than boiling. The consumption of solar hot water and solar space heating was estimated at 88 GW in 2004.

## 14. CONCENTRATING SOLAR POWER (CSP) FOR ELECTRICITY GENERATION AND PROCESS HEAT

Heat for chemical processes (mainly steam) at a temperature of 120 to 250 °C can be produced by concentration of direct sun rays. This is used mainly in countries where direct sun rays are sufficiently available as it does not work satisfactorily with diffuse light.

To produce electricity, steam at temperatures of 250 to 500 °C is required. For this purpose a high concentration is essential.

In California a solar power plant with mirror concentrators shaped to rows of parabolic troughs works since 20 years; its total capacity is 354 MW (Figure 1). The troughs are tracking the sun from east to west concentrating the sun rays on a tube in its focus. A thermo-oil flowing in the tube is heated to 393 °C and gives its heat through a heat exchanger to generate steam at about 385 °C that drives a conventional steam turbine. Interesting at this technology is that the electricity generation may continue in the night using a backup fossil boiler or heat storage, thus getting what the electricity producers call “Electricity on demand”. Heat storage is now available with molten salt and special concrete. Further research is ongoing and promising to produce phase change storage, thus maintaining constant temperature during the storage time. In Spain two CSP plants are now in construction and six others are planned, some of them with heat storage having storage efficiency better than 80 %.

Fig. 1. Concentrating solar power plant with parabolic mirrors in California.

A further development of the trough technology is to segment the parabolic shape in several flat mirrors called "Fresnel mirrors" (Figure 2) which are proposed to be installed in Northern Africa's desert [25, 26]. Only the segments follow the sun. The reflected light is concentrated to fixed tubes, the contained water vaporises up to temperatures of 350–500 °C. The superheated steam is used to drive turbines. After sunset the mirrors are turned to face the bottom and are cleaned with water from below. That water can be used to irrigate profitable plants.

Another CSP technology is the Solar Tower. It consists of several mirrors called heliostats placed in nearly half a circular area and tracking the sun in such a way that they concentrate the sun rays on the top of a tower. The concentration is much higher than that of parabolic troughs and reaches temperatures of 1000-1200 °C. This enables using the heat in a combined cycle (Gas turbine + steam turbine) having an efficiency of about 55% (compared with the steam cycle efficiency 35–37 %). Storing the heat at that high level is obviously more complicated than that at 300–500 °C. This technology is promising for hydrogen production by directly reducing water vapour using a catalyst, which in turn gives back oxygen. Thus both gases are produced without generating $CO_2$ and are therefore ideally suited to drive "Clean Cars" and other $CO_2$-free applications

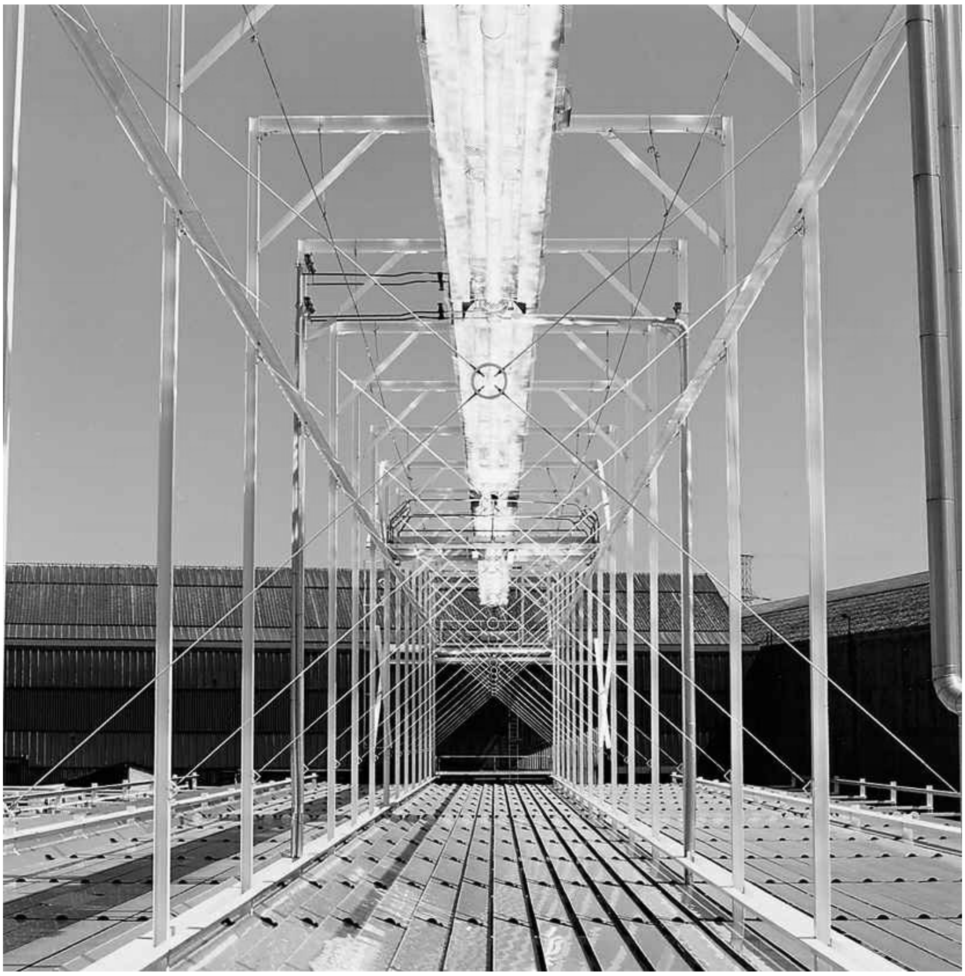

Fig. 2. Concentrating solar power plant with Fresnel mirrors.

Waste heat, which is always produced during steam condensation at the end of the steam turbine process, is used for desalination of sea water by vaporisation. This is an interesting second product in countries with abundant sun rays, as in these countries water scarcity is a serious problem. Also reverse osmosis may be used for seawater desalination in case that enough cheep electricity is available.

## 15. ELECTRICITY TRANSPORTATION – OIL/GAS TRANSPORTATION

Today electric current could be produced in Egypt for about 9-6 ct/kWh and transferred to Europe by high voltage DC for about 2-1 ct/kWh; a study showed that these costs will be reduced to 4ct/kWh for production and 1ct/kWh for transportation over 4000 km. In comparison:

- 1 nuclear power plant may produce ~ 1000 MW
- 1 $km^2$ Fresnel mirror can produce ~ 100 MW
- 1 $km^2$ wind rotor can produce ~ 10 MW

That means that 1 nuclear power plant could be replaced by 10 $km^2$ mirror or, with storage for night operation by 30 $km^2$ mirror.

## 16. THE POLISH SITUATION

Poland possesses abundant coal deposits and met roughly 24% of their natural gas consumption demand with domestic sources in 2001 [27]. Coal industries have continually restructured, downsized and the number of inefficient mines in operation has been reduced. The strategic importance of the-called Visegrad region comprising Poland, Czech, Slovakia, Hungary, however, lies largely in the traversing crude oil and natural gas pipelines on their way to Western Europe. The Visegrad region is a key transit centre for Russian natural gas exports to Western Europe. That countries share also the CENTREL electricity system including a new link to Lithuania. From the economical point of view there are no concerns in the Polish situation of energy supply except for the large production of $CO_2$. In agriculture organic waste could be used for gas production and at isolated locations the use of wind power could cover own requirements.

## 17. CONCLUSIONS

Considering trouble, costs and ethic reasons of a world's increase in temperature the use of fossil energy should be replaced as far and as quickly as possible by alternatives. Saving in consumption and producing renewable energy will be helpful. At present, only nuclear power plants and concentrating solar power plants are able to meet the large requirements. Regarding the limited resources of nuclear fuel, costs and problems of nuclear techniques urgently solar techniques should be developed for an extended application.

## 18. PROGNOSIS

- Optimistic: In contrast to past societies we know what we do and we have enough information to assess the consequences. Therefore we are able to moderate the temperature increase and to plan corrective measures.
- Optimistic: The climatic change problems are regarded as important and discussed worldwide.
- Optimistic: Many counter measures in alternative energy production and energy saving have been developed.
- Pessimistic: Investments in the development of alternatives are low in comparison to investments for the extension of fossil energy production and distribution. Because the period for planning and development is in the range of 20–30 years a switch to alternatives cannot be expected.
- Pessimistic: In Germany operating nuclear power plants will be shut down and replaced by fossil plants.
- Pessimistic: there is no lobby for concentrating solar power.

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