OVERALL ENERGY POLICY
AND THE ADVANTAGES OF
RENEWABLE ENERGY TECHNOLOGIES
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Content

Sustainable development and energy supply

"Humanity has the ability to make development sustainable - to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organisation on environmental resources and by the ability of the biosphere to absorb the effects of human activities"
"... sustainable development requires meeting the basic needs of all and extending to all the opportunity to fulfil their aspirations for a better life. "
("World Council on Environment and Development", Brundlandt Report, 1987)

The idea of sustainable development is based on a recognition of the equal rights of both present and future generations, in all continents, to the fulfilment of their basic needs and requirements. In order to meet these aspirations to a better life in a spirit of equal rights, an environment must be maintained in which all human beings can live naturally, i.e. without technical aids. The Earth and its inhabitants are linked in a system of mutual dependence. In the course of recent history, one group of these inhabitants, human beings, has brought about increasing imbalance in this intricate network of interactions and interdependent cycles. The Earth's "survival" system consists, from the human point of view, of basically two domains - the technosphere and the biosphere. The technosphere digests minerals, rocks, metals, water, air, fuels and biomaterials in all their varieties and creates "wealth" and waste at all levels. The biosphere is the domain in which flora and fauna seek to survive according to the rules of evolution and according to the given anthropogenic circumstances. The survival of human beings is dependent on both of these sub-systems.

Science today still knows very little about these sub-systems, and has hardly even begun to investigate some parts of them. One of the most widely researched aspects is the Earth's climatic system. Massive expenditure on personnel and technology has been required to establish just a few prognoses of the future behaviour of the climatic system, such as the development of average world temperature. What science has learned from such analyses is that the biosphere and technosphere are extremely complex systems permanently undergoing reorganisation. The basic laws governing the behaviour of the sub-systems are non-linear and minor causes may lead to sudden, major effects over a short period of time. Science can provide little, if any, information on the effects of human action, either with regard to the intensity of the ecosphere's reaction or with regard to the time scale involved. The discovery of the ozone hole is a good example of this. The substances which now threaten the stratospheric ozone layer would have passed every single ecobalance test known to man before their effects in the stratosphere were discovered.

At this stage in history, and perhaps for all time to come, our actions must be guided by this recognition of how little we know about our Earth's "survival" system and its susceptability. As a precautionary measure, we should therefore attempt to minimise anthropogenic effects on this system, and thus prevent as far as possible any negative consequences. This precautionary principle must constitute the main guideline for all human activity if sustainable development is to be our primary aim. To argue that ways will be found to "repair" the biosphere later is both arrogant and irresponsible, for it implies the assumption that we are capable of repairing a system which science has so far failed to fully comprehend, and, secondly, it ignores the fact that such global effects as reduction of the stratospheric ozone layer or the climatic changes undergone by the Earth are quite simply phenomenon which are beyond "repair".

Presupposing a recognition of our lack of knowledge, an adherence to the **precautionary principle** of minimising anthropogenic energy and material flows, and an endorsement of the principle of just, sustainable development, the question now poses itself as to what this will mean in terms of appropriate energy technologies.

What does the profile for a sustainable energy system look like?

No global inter- or intragenerational risks: the operation of a sustainable energy technology should involve neither direct nor indirect effects which may impede the development of future generations. Material flows, even of naturally occuring, harmless substances, should be as small as possible.

"Waste" from an energy technology, if it cannot be avoided, should then be in the form of substances already occuring naturally in the biosphere. If substances which do not occur naturally are produced through the use of an energy technology, long term storage facilities must be provided, and, to achieve maximum possible isolation from the biosphere, dissipative losses, where unavoidable, should be low (i.e. only a very small proportion of the total quantity used should end up being finely distributed in the biosphere, e.g. as a result of leakage or evaporation). The system should make it possible for any technology which is later perceived as dangerous or undesirable to be withdrawn and its waste products to be immobilised to the greatest possible degree.

Energy technologies must not be based on **finite resources**, since these will be exhausted sooner or later and will therefore not be available to future generations. In addition, a sustainable energy system should have sufficient inter- and intragenerational potential.

A final, essential point is that such energy technologies must not contribute to **political instability**, i.e. constitute a security risk, and it must be possible to use them in many regions all over the world. This applies particularly to technologies with high toxic hazard potentials or where the substances may be misused for military purposes, as is the case with plutonium. In both cases a high degree of supervisory authority is required, and this can easily be abused.

All these conditions are met only in part, if at all, by energy technologies currently in use, and it is unlikely that any single technology will ever completely fulfill them. They do, however, provide a fundamental yardstick for decision-making with regard to technologies or combinations of technologies now being considered for use in the energy system of the future.

World-wide consumption of primary energy is based on fossil fuels (oil 35 %, coal 27.5% and natural gas 22 %) followed by renewable energy sources (biomass, wood, so-called non-commercial fuels 5.8 %, water 4% and others 0.5%) and finally nuclear energy with a level of 5%. In 1991 this corresponded to a primary energy use of 11.6 billion coal units[1]. In the year 1992 the twelve european countries consumed 1.8 billion coal units of primary energy, mainly fossil fuels (oil 44.3 %, coal 20.6% and natural gas 18.5 %), nuclear energy with a level of 14.5 % and renewable energy sources with 2 % [2].

Fossil fuels

With fossil fuels there are major differences of geographic distribution between main areas of consumption and the locations of reserves and extraction sites. The largest spatial imbalances in terms of supply and demand apply to the **mineral oil reserves**. In 1992, for example, the group of the ten largest oil consumer countries included only four of the countries with the richest oil resources. The calculated static range of oil reserves[3] is 43 years on an international average /Jahrbuch Bergbau 1994/. Because of their large reserves countries in the Middle East will have a key role in the long term. These countries produced 28% of all the oil (domestic consumption 5%) in the world in 1992, while Western Europe consumed three times as much oil as it produced. Japan has no oil reserves of its own.

The pattern is similar with regard to world-wide distribution of **natural gas reserves**. Countries in the Middle East and the former USSR possess over 70% of world-wide mineral oil and natural gas reserves. The static range of natural gas reserves is 65 years on a world-wide average. In contrast to mineral oil, where more than half of the oil produced is traded with other countries, natural gas is predominantly used in the countries where it is produced, with international trade accounting for only 14% of the total (illustration: natural gas producers/natural gas consumers).

The main locations of **coal reserves** are in the USA, the former USSR and in Asia (in particular China, India and Indonesia). Although by weight these reserves comprise equal shares of lignite and mineral coal, in terms of energy content, mineral coal makes up some 70% of the total reserves. The static range of mineral coal is 150 years and that of lignite 500 years. Because, in comparison to mineral oil or mineral coal, lignite has a high water content and a low calorific value, its transportation over large distances is not economically viable. This is also reflected in the level of international trade in this fuel - just 0.4% of lignite production, as against approx. 12% of mineral coal production, is traded on the international market.

The use of fossil fuels always results in the combustion of carbon and the consequent creation of carbon dioxide.

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[1] Energy Statistics Yearbook, UN, New York, 1992

[2] EUROSTAT, Luxembourgh, 1994

[3] static reserve = range if production stays at the same rate, in this case the production rate in 1992

Global climate change - the greenhouse effect

One of the main anthropogenic impacts on the Earth's biosphere is the alteration of climate through greenhouse gas emissions. The climate of the Earth is controlled by a very complex system in which different elements and subsytems (atmosphere, biosphere, oceans, ice areas etc.) are interrelated through feedback loops. Although they are so crucial, the processes, interactions and interdependencies between and within these elements and subsystems remain largely unknown. The driving source of energy for our climate is the solar radiation which reaches the Earth. This radiation is partly reflected and partly absorbed by different elements of the Earth's system. The energy absorbed from solar radiation is balanced by outgoing longwave radiation (invisible infra-red). Radiative input varies, one reason being variations in the Earth's orbit, another the variation of solar radiative output, e.g. as in the 11 year solar cycle.

If, on average, outgoing infrared radiation balanced incoming solar radiation, the surface of the Earth would have a temperature of - 18°C. But the mean near-surface temperature today is +15°C. This temperature difference of 33°C is due to the effect of the Earth's atmosphere and the greenhouse gases (water vapour, carbon dioxide, ozone, nitrous oxide, methane). Greenhouse gases permit incoming short wave radiation to pass through the atmosphere, while they partially absorb and reflect outgoing long wave radiation, thus creating a warmer atmosphere and higher surface temperatures. The contributions of the individual greenhouse gases to this "natural" greenhouse effect are: water vapour 20.6°C, carbon dioxide 7.2°C, ozone 2.4°C, nitrous gases 1.4°C and methane 0.8°C.

Carbon dioxide is one of the important greenhouse gases. Looking back through history, we find a clear correlation between carbon dioxide levels and variations of temperature over the last 160 thousand years. In recent times, mainly due to the burning of fossil fuels, carbon dioxide concentrations in the atmosphere have been increasing faster than ever before. The atmospheric carbon dioxide concentration has increased from 280 ppmbv at the beginning of the industrial revolution to a value of 353 ppmbv today. Atmospheric carbon dioxide concentrations shows an exponential growth during the last two decades. If the carbon dioxide emissions rate of 1990 is projected to the year 2100, the Earth's atmosphere will have a carbon dioxide concentration of approximately 500 ppmbv, 40% higher than current levels. Emissions resulting from human activities (agriculture, landfills, etc.) are substantially increasing atmospheric concentrations of other greenhouse gases like methane and nitrous oxide. We have even introduced a new group of greenhouse gases, the chlorofluorocarbons (CFCs) with a greenhouse potential several thousand times greater than carbon dioxide. It is reasonable to assume that the increase of concentrations of carbon dioxide and the other greenhouse gases will lead to a rise in mean global temperature during the next few decades.

How great and how fast will this climate change be? Two commissions have tried to answer this question. The first is the Enquete Commission of the German Bundestag "Preventive Measures to Protect the Earth's Atmosphere", the second the "Intergovernmental Panel on Climate Change" of the United Nations and the World Meteorological Organisation. Predicting future behaviour of the climate system means knowing what the levels of carbon dioxide emission will be during the coming decades. In one of the scenarios of the Enquete Commission the industrialised countries will reduce their carbon dioxide emissions by the year 2100 to one quarter of their present levels while world emissions will go down to a half of today's values. This presupposes the most rigid of climate protection measures, but even in such a "tough" scenario simulations of the future climate system indicate significant rises in temperature of between 1.08 and 2.38 degrees. Depending on climate sensitivity and on the scenario chosen, predictions of the increase of mean global temperatures by the year 2100 range from 1 to 4 ˚C [4]. Assuming "best estimate" climate sensitivity, all scenarios investigated by the IPCC predict mean temperature rises of between 1.3 and 3.5 degrees by the year 2100 [5]. According to the Enquete Commission the relative contributions of specific areas of human activities to climatic changes will be: 15% through deforestation, 50% through energy systems, 20% through chemicals and 15% through agriculture.

There are still some areas of inadequate knowledge in these predictions such as cloud interaction, aerosols, the water household of the atmosphere or the role of oceans in terms of their thermal inertia and of possible changes in circulation. But there is now enough conclusive evidence from results of different simulation models that global warming will occur in the coming decades.

What will the consequences of this global rise of temperature be? There will be a shift of climate zones. In principle this is nothing serious. The biosphere has gone through this many times in its history. The problem is that this shift of climate zones will be fast, impacting on flora and fauna in such a way that biodiversity will decrease. Another consequence will be an increase in extreme weathers (storms, hurricanes, etc.), resulting from an increase in energy in the lower atmosphere due to warmer surface water and a higher humidity in surface air. There will also be a change in global precipitation patterns. This is highly relevant as it will force changes in patterns of agricultural exploitation and affect the productivity of agriculture and forestry, with unforeseeable consequences for food distribution.

Three parameters clearly correlate, sea level rising was observed every time carbon dioxide and temperature increased. The rise in sea level to be expected by 2030 in a "business-as-usual" scenario is about 20 cm, and, even if emissions are stopped completely, simulations show that the sea level will continue to rise for many decades to come, increasing the hazard of sudden floods.

How fast do we need to change our energy system? The present energy system is unsustainable, and a new one must be developed. In the scenario which needs to be realised in order to stabilise the climate system at current values the industrialised countries will have to reduce their carbon dioxide emissions by 2100 to one quarter of their present levels, while world emissions will go down to a half of today's values. Calculating on the basis of equal per capita emission of carbon dioxide

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[4] "Protecting the Earth", Status Report with Recommendations for a New Energy Policy, Study Commission of the German Bundestag "Preventive Measures to Protect the Earth's Atmosphere", 1990.

[5] "Climate Change - The IPCC Scientific Assessment", 1990 and "Climate Change 1992 - The Supplementary Report to the IPCC Scientific Assessment", 1992, Intergovernmental Panel on Climate Change.

worldwide, just stabilising total emissions in the year 2020 at 1990 levels will require the OECD countries to **cut back to 15%** of today's emissions by 2020.

Nuclear energy, fission and fusion

Nuclear energy today is used around the world solely for the generation of electricity. Over the last few decades, Japan, Western Europe and North America have considerably increased the proportion in which their electricity needs are met by nuclear power stations. In 33 countries around the world, a total of four hundred and twenty-two nuclear power stations were on line in 1992 with an installed rating of 56 TW. They generated 17% of world-wide electricity production[6]. Production levels differs greatly by region. The majority of the world's uranium reserves are in Australia, South Africa and Canada, amounting to 2.1 million tons of uranium with a static range of approx. 60 years. The range may be increased by breeding plutonium, a radioactive and highly toxic material with a period of half-life of approximately 25,000 years.

The use of nuclear fission to generate electricity always involves the production of radioactive nuclides. These cannot be totally isolated from the biosphere throughout the entire fuel circulation. Dissipative losses always lead to the release of certain quantities of these highly enduring substances, which combine with nature and slowly but surely increase the planetary radiation level. The final storage of waste from these technologies, a problem which remains to be solved, and the risk of accidents with high release rates of radioactive materials is an additional hazard. Nobody can say as yet what effects this radiation will have on nature in the long term.

An additional problem is that reprocessing systems and final storage facilities will require permanent supervision for generations to come because of their high risk potential for human beings and nature. Should a plutonium-based system becomes established, there will also be an acute risk of proliferation of nuclear weapons. Recent examples of trade in radioactive nuclides from the former USSR show how impossible it is to control this hazard. This and further evidence clearly indicates that nuclear fission cannot be an option for a long term energy system.

Nuclear fusion, the other potential exploitation of nuclear energy, involves the fusion of light atomic nuclei to form heavier ones. This principle was applied in the hydrogen bomb to achieve even greater explosive power that the nuclear fission bomb. The sun also breeds its energy by a process of nuclear fusion. To achieve the fusion of a large number of atomic nuclei, hydrogen must be heated to a temperature of several million degrees and compressed. In this condition it is known as plasma. To ensure that the plasma does not come into contact with the surrounding material of the combustion chamber (because no material on earth can withstand such temperatures), it is held suspended within a magnetic field. Of the conceivable types of controlled fusion reactions, the fusion of deuterium and tritium produces the most effective energy yield while at the same time ensuring the lowest possible plasma temperature. Tritium is a radioactive isotope of hydrogen with a

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[6] In 1992 the totalled world wide electricity production was 12,200 TWh.

period of half-life of 12.3 years. It is only found in traces in nature, but may be bred from lithium through neutron bombardment. Deuterium and lithium are available in reserves which are equally distributed around the world, and are sufficient to ensure a very long-term utility for fusion power stations.

The idea of the fusion reactor was born fifty years ago. In the sixties, the invention of the Tokamak principle inspired forecasts of a first fusion reactor being ready to go on line in the nineties. At the start of the seventies, prognoses postponed the arrival of this new type of reactor until the first decade of the next century, in the last years it is again postponed until the middle of the next century. So far no functional fusion power stations exist, not even on the drawing board.

One of the problematic aspects of these power stations of the future, if it ever is possible to bring it to function, is the radioactive nature of tritium. Tritium can penetrate solid materials, and this effect is enhanced as the substance is heated. It attains very high temperatures both in plasma and in the breeding blanket, and, if it diffuses into the air, it may be converted into tritiated water, thus creating environmental and safety problems. The use of lithium presents another problem, as it is a highly corrosive substance which will further reduce the service life of the thin first wall around the plasma. If lithium is released it may cause an extremely hot fire. Such a fire might lead to the release of the entire stock of lithium and, after the first wall is breached, also of the entire stock of radioactive isotopes enclosed within this first wall.

Even if solutions can be found to all the technical and scientific problems, several questions remain which must be answered at this moment in time. Will it be possible to generate electricity at a reasonable price in view of the expected service lives of components of between two and ten years? And, more importantly, will this type of energy production achive economic viability, and if so, after how many years? There are no conclusive answers to either of these questions at present. And, much worse, the cost estimates, based on extrapolations from current experiments which have still not managed to generate electricity profitably, vary by a factor of about 5 and are at least three times as high as in the most expensive nuclear fission power stations.

Assuming for a moment that even this problem can be solved satisfactorily, there is still the question as to how many ecological risks the intensive use of nuclear fusion will present. If nuclear fusion is to be a major component of future energy systems, we must expect between 500 and 2000 reactors to be built around the world with a rating of 1,000 MW. Such reactors will produce five times as much medium and highly radioactive waste as corresponding nuclear fission reactors in the course of their service lives of 30 years.

During normal operation of a fusion reactor, losses resulting from accidents (fires, other faults, etc.), maintenance work and the unavoidable dissipative losses will result in tritium being released in quantities which cannot as yet be assessed. Tritium is a ß radioactive substance with a half-life of 12.3 years, so this radiation has a very short range. However, if it is released into the body, it will lead to extensive cell damage. Of the two chemical formulae in which tritium occurs, namely the gas T2 and tritiated water HTO, HTO presents far greater problems. It acts like water, i.e. is absorbed into fauna and flora, thus entering all living things through the food chain causing hitherto unknown effects and problems for the entire biosphere.

Although nuclear fusion is currently not a viable energy technology, it is impossible to say whether a power station based on this technology will be able to work properly in 30 or 50 years time. However, the real danger of a cumulative contamination of our environment is sufficient reason, as in the case of nuclear fission, to view this technology as a non-sustainable technolgy.

Renewable energy technologies

Humanity has for years had a reactor at its disposal which will support a fusion process without environmental problems or additional research. With a mass some 3,332,270 times that of the Earth, the sun produces radiation energy at a rate of 1.3 kW per square metre for each and every square metre of the Earth's surface. And it wll continue to do so for several million years to come.

National security policies of the industrialised countries are greatly influenced by considerations of energy supply. The Gulf War, with an estimated cost of 60 thousand million dollars, was a war fought to secure oil reserves for the industrialised countries. Renewable energy technologies are reliant on resources which are extensively available all over the world, and reduce the opportunities for exploitation of energy dependency in two ways. Firstly, countries (even outside the sun belt) can achieve high levels of energy autonomy through efficient use of domestic renewable sources, and, secondly, almost any country within the sun belt can provide energy for export. This high potential level of domestic energy supply and the possibility for many developing countries in the sunbelt to become energy exporters will certainly change the balance between the industrialised nations and the third world. Renewable energy is mostly produced decentrally, no huge construction complexes are necessary, and the absence of large concentrations of chemical or even radioactive materials which might provoke power struggles or attract terrorist attacks contributes to the low political risk factor of these technologies. These, and the high level of social acceptability of most solar power technologies, are further positive aspects. The majority of the technologies necessary to exploit renewable energy sources are already at the disposal of all the countries of the world, so there is no need for tensions to develop between technological haves and have-nots. The equal distribution of resources, the general accessibility, and the low social implications of renewable energy technologies have led to a high acceptability of these technologies.

Many energy technologies today harness the energy provided by the sun. To our current knowledge, the exclusive use of only one of these technologies, e.g. biomass, to solve the energy problems of the future would also carry risks for the environment. But the combined use of these technologies would turn what is generally regarded as a disadvantage of renewable energy technologies into an advantage.Systems which use renewable energy sources have a very low rating density. As a comparison, a coal-fired power station has a rating density of 500 kW/m2, wind energy one of less than 3 kW/m2, solar energy less than 1.35 kW/m2 and biomass production approximately 0.0002 kW/m2. In short, a power station which uses renewable energy sources needs a great deal more area to produce the same amount of energy as a conventional power station. However, these rating densities also indicate the impact on the local biosphere: the lower they are, the lower the effect.

Renewable energy technologies and their impact on the biosphere

There is no technology, not even renewable energy technologies, which does not have an ecological price. Even in the case of renewable energy production, there is "waste" which must be kept to a minimum. This chapter will deal with the most important currently recognised problem areas of renewable energy sources. From the perspective of environmental protection, the fundamental difference between conventional energy sources (oil, coal, gas and uranium) and renewable sources is that production of energy from the latter involves no chemical transformations. In the case of biomass, energy conversion does not result in the emission of climatically hazardous substances, radioactive substances or toxins. It is true that use of biomass produces carbon-dioxide, but the substances being emitted into nature were taken from nature earlier, during the growth process of the biomass. However, as with all incineration processes, environmentally hazardous substances present in the fuel may be released, and nitrogens and other typical emissions must be minimised through appropriate preventive measures. One could argue that the carbon dioxide emitted during the combustion of oil, coal and gas is also only being returned to nature, from which it was taken ages ago. But there is an extreme imbalance between the amount of time required to take it and the speed with which this carbon dioxide is being returned to nature. It is only if the growth of a natural raw material and its exploitation by human beings both occur within a comparable period of time that this energy use deserves to be classed as sustainable.

So, while the actual process of technological transformation of renewable sources into energy for human consumption has hardly any effect on the environment, the situation is somewhat different with regard to the stages which preceed and follow this process. The production and installation, and the disposal or recycling of windmills and solar panels involve conventional manufacturing processes and are therefore not emissions-free. Such emissions, and the environmental impact of the technological exploitation itself need to be fully recognised and kept to an absolute minimum, if not totally prevented.

A further factor which must be taken into consideration for ecological reasons is the **flow of materials** and energy which an intensive exploitation of renewable energy sources would bring with it. Probably the greatest material and energy costs would be needed for photovoltaic energy production (see Table). The material flow for the centralised photovoltaic power station seems high in this comparison. Such mass flows are unnecessary if the modules are installed decentrally on buildings roofs or facades. This indicates that it only makes ecological sense to apply photovoltaic technology in a decentralised way. The comparison shows that, even when least favourable values for material and energy flows are considered, photovoltaic technology still causes smaller flows than in the case of a coal-fired power station [7]. The figures clearly demonstrate, on the one hand, that even photovoltaic energy does not come without an ecological price tag, but, on the other hand, that exploitation of the conventional energy source coal involves much greater material and energy flows than photovoltaic technology. The specific values per kilowatt hour for photovoltaic energy production can be further reduced in sunny regions without any additional technological further development, since a solar cell in southern Spain provides twice as much elecricity per year as it would in mid-Europe. Technical innovations like improved efficiency and the development of thin-film solar arrays will make further reductions of material flows possible.

	Concrete (g/kWh)	Steel (g/kWh)	Copper (g/kWh)	Silica sand (g/kWh)	Energy needs (g SKE/kWh)
Photovoltaic centralised (1)	50	11	2	10 - 25	128
Photovoltaik decentralised (1)	0	0.2	-	10 - 25	112
coal-fired power station (2)	12	3	0.013	-	340

Table : Comparison of material and energy requirements for
(1) a monocrystalline solar module, service life 20 years, mid-European sunlight conditions, 1000 hours operating time per year
(2) a 450 megawatt block, gross production 2380 gigawatt hours per year
Source : Lewins, B.; Hagedorn, G.; Hellriegel, E.; Hantzsche, U.; Dones, R.; Zollinger, E.

An example calculation shows that the energy production potential of one kilogram of silicium compares competitively with that of one kilogramm of enriched uranium. At present, fission reactors use about 0.0043 grams of enriched uranium to produce one kilowatt hour of electricity[8]. This corresponds to about 230 megawatt hours of energy from one kilogram of enriched uranium. In contrast, a photovoltaic module of amorphous silicium, the most economical variant of photovoltaic technology with regard to materials needs, requires about 0.01 grams of the gaseous silicium com-

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[7] a) Lewins, B.: CO2-emissions from energy systems for the production of electricity with the energy transformation chain taken into consideration; Fachbereich 16 Bergbau und Geowissenschaften der Technischen Universität Berlin, Berlin 1993
Hagedorn, G.; Hellriegel, E.: Environmentally relevant material flows in the production of various solar cells; Environmental compatibility testing of research projects - with the example of photovoltaic technology -; Vol. 5; Report of the Research Centre Jülich (Forschungszentrum Jülich - KFA) in the series: Applied systems analysis of the programme group STE No. 67; Jülich 1992 and Hantzsche, U.: Process chain analysis of building and utility materials: Production of flat glass; Research Centre Jülich (Forschungszentrum Jülich - KFA); Internal Report KFA-STE-IB-8/91; December 1991

[8] a) Dones, R.; Zollinger, E.: Eco-Inventary for energy systems, Part VII Nuclear energy, Bases for an ecological comparison of energy systems and the inclusion of energy systems in an eco-balance for Switzerland; ETH Zürich 1993
b) Hagedorn, G.; Hellriegel, E.: Environmentally relevant material flows in the production of various solar cells (see above)

pound hydrosilicon (SiH_4) to produce one kilowatt hour of energy. One gram of hydrosilicon contains 0.88 grams of silicium. This corresponds to an energy yield of 114 megawatt hours from one kilogram of silicium, i.e. half the efficiency of uranium. If, however, the same type of module is used not in central Europe, as assumed in the example, but in southern Europe, twice the amount of energy yield can be achieved. In these regions, therefore, about the same amount of electricity can be generated from a kilogram of silicium as from a kilogram of uranium - with one important difference: silicium can be recycled or easily disposed of.

Particularly critical attention needs to be given to those **solar arrays which contain heavy-metal compounds** like gallium arsenide or cadmium telluride instead of relatively harmless silicium. Special precautionary measures are required where such panels are manufactured or employed, e.g. in case of fire, and appropriate recycling procedures are absolutely essential. But a deposit-refund system, for example, could help to ensure that solar modules with critical components do not end up on a landfill, or in a waste incinerator, where such heavy metals might be mobilised [9]. One could however ask whether, in view of the impact which could occur through such heavy metal modules, this technology should not be abandoned altogether in favour of safer silicium technology.

There is great public controversy whenever discussion focusses on the **energy amortisation time of photovoltaic modules** and plants. The question is repeatedly posed as to whether a photovoltaic power plant can actually produce as much energy during its service life as must be invested in its production. It is true that, currently, photovoltaic technology, of all the renewable energies, needs the most energy for its production. The energy amotisation times of the different varieties of solar cells differ greatly. The production of mono-crystalline silicium uses considerably more energy than is required in the manufacture of cells made with amorphous silicium. The actual construction of the modules - with aluminium frames or without frames - can also have a positive or negative effect on the energy balance. Another decisive factor is the installation concept, i.e. the decision between a free-standing, centralised plant or the integration of the modules into roof or facade structures in the immediately vicinity of the end-consumers.

In a detailed study on the material and energy requirements of centralised photovoltaic power plants from production to recycling or disposal, Gerd Hagedorn et al [10] have established that, in middle European locations, the invested energy is recouped within seven to ten years of service. The period of seven to ten years is called the "energy-pay-back-time". What this means is that, after thirty years

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[9] a) Hirtz, W.; Huber, W.; Kolb, G.: Environmental compatibility testing of research projects - with the example of photovoltaic technology; Programme group systems research and technological development, Research Centre Jülich (Forschungszentrum Jülich GmbH); December 1993;
b) Karus, M.; Wittassek, R. und Linden, W. : Environmental aspects of the use of Cadmium-Telluride-solar cells; Katalyse Institute for applied environmental research; Cologne, May 1990 and STE 1991 : Environmental effects of the use of solar cells; Programme group systems research and technological development, Research Centre Jülich (Forschungszentrum Jülich GmbH); November 1991

[10] Hagedorn, G. and Hellriegel, E.: Cumulative energy consumption for the production of solar cells and photovoltaic power stations; Research centre for energy economy (Forschungsstelle für Energiewirtschaft - FfE); Munich, July 1989

of operational service, the plant will have payed three or four times over for the energy invested in its production. The service lifespan of solar cells lies between twenty and thirty years. In southern countries the amortisation time is only half as long. Future developments will further improve energy efficiency. A simply move to modern mass production procedures will bring substantial gains. The authors calculate that the energy pay-back time for mass produced series would be as little as three to five years. A new study commissioned by the EU arrives at substantially better energy pay-back time prognoses by taking newer production processes into consideration. According to these findings, multi-crystalline silicium modules in middle European sunlight conditions break even after 2.3 years, and amorphous silicium cells after only 1.7 years [11]. And these energy pay-back times could be even further improved through mass production techniques.

The use of regenerative energy sources not only causes material flows, it also has an impact on flora and fauna. Here, the greatest problems are caused by **hydropower** stations. Radical change to large tracts of land in ecologically sensitive regions, for example in tropical rainforest areas, is only one of many problems. The conclusion to be drawn from several studies is that large-scale projects sometimes do more damage than good. This is one more good reason to encourage and expand exploitation of hydropower through smaller power stations. However, large-scale projects should not be dismissed out of hand, and each case should be judged according to its particular merits.

Wind energy has often come in for heavy criticism in terms of the potential hazard to bird life. Several studies have already been conducted in Germany and in neighbouring countries to assess the validity of such concerns. A study commissioned by the Federal Ministry for Research and Technology (BMFT) and conducted by the North German Academy of Nature Conservation investigated eighty wind installations in ten various locations in Lower Saxony and Schleswig-Holstein. The statistical results showed that over the period of a year (1989/1990) at seven locations with 69 plants (no statistics were documented for the other three locations) probably a total of 32 birds died as a direct result of wind power technology. Compared to the number of birds which die through collision with other structures or through road traffic, the fatality rate for windmills is of lesser significance. For example, during the period April 1989 to August 1990, 418 dead birds were counted on a radio tower on the Island of Sylt [12]. Comparative studies in the Netherlands and Denmark confirm that wind power plants, whether in Lower Saxony or Schleswig-Holstein, do not represent a serious threat to bird life. It would appear that migratory birds are sufficiently warned by the noise and movement of the windmills rotors to avoid them, and risk of bird collison could be considerably reduced by colouring the windmills. The results quoted refer to windmills located at least 400 metres from the dyke line. If wind power installations are set up in the immediate vicinity of the dykes, on the land in front of the dykes, or on the embankments themselves, the risk of bird collision will be higher. This is because dykes are used as orientation lines by migratory birds, and

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[11] Palz, W. and Zibetta, H : Energy pay back time of photovoltaic modules; International Journal of Solar Energy Vol. 10, 3/4.

[12] Vauk, G.: Biological-ecological parallel study to the construction and operation of wind power stations; NNA-Reports 3/special volume, Schneverdingen, 1990

the whirlwinds which often occur at the dykes might blow birds into the rotors. Another factor is that the areas in front of the dykes are often the preferred resting and feeding grounds of the birds. If the location of installations, especially wind parks, is carefully selected, this ecological impact is fully avoidable.

Biomass : The cultivation and exploitation of energy plants can help to reduce carbon dioxide emissions and in this way have an ameliorative effect on global climate. But this potential positive effect could end up being cancelled out or even negated if long established methods of cultivation are taken over from conventional agriculture and forestry. The greatest dangers are the farming of monocultures and the intensive application of fertilisers and insecticides. A sustainable energy economy which intends to grow and use biomass cannot base itself on over-intensive agricultural practices without completely contradicting itself. The selection of energy plants must ensure that the best possible crop or crop mix is found for each given location. The selection criteria must include the climatic conditions, the soil characteristics and the surrounding flora and fauna of the site in question.

Short-cycle forests need hardly any fertilisers if leaves and twigs are left lying on the ground. Another strategy is to select plant species which use nutrients to a particularly high degree of efficiency. There is an abundance of such varieties. It has been established, for example, that Miscanthus yields cannot be raised any further by adding more nitrogen. In addition, nutrients are deposited back into the roots at the end of the vegetation period and remain stored there over the winter. Use of nitrogen fertilisers can therefore be reduced to minimal values of between zero and fifty kilograms per hectare per year [13]. Other nutrients like phosphor, potassium and magnesium are contained in the residues of biomass combustion and can be returned to the fields. In this way the nutrient cycle can be kept relatively closed. And when cultivation of domestic plants on degraded soils has become difficult or even no longer possible, energy plants may be a means of restoring these areas.

Biodiversity - the variety of the species. The possibility that energy plantations may endanger biodiversity is a frequently cited criticism. At present only a half a percent of all the plants in the world are used for food production. If additional energy plants were cultivated on agricultural land areas, this would actually lead - in comparison to the present pattern of land use - to an increase rather than a decrease in biodiversity. The argument that biodiversity is threatened is, however, valid when, for example, short-cycle forests replace natural forest stands. But if this is not the case, if it is in fact agricultural monocultures which are replaced, and if already degraded areas are planted with energy crops, then this can only have a positive effect on the biological diversity of the countryside

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[13] Albert, R.; Lazu, L.; Lütgert, J.; Ney, P.; Owsianik, E.: Ecological-energy balance of regenerative resources (reeds); Environmental Protection Service GmbH, March 1993

[14]. Since the only really relevant factor in the cultivation of biomass for energy production is the combustable carbon bound in the vegetation, mixed crops of plants can be grown on the same land. This also increases biodiversity and creates additional habitat space for local fauna. Mechanical harvesters which can collect such biomass mix (bushes, reeds and grasses) in one go and prepare it for energy production (e.g. by shredding it into standard lengths) are already on the market.

No **noise**, or very little noise, is produced when solar energy is directly converted into utilisable heat or electricity. This kind of environmental impact is only created by moving components or installations. Solar-thermic and photovoltaic energy production requires no moving parts, except for the conventional technological components of, for example; a solar-thermic power station or the electric motors which move the reflectors - all technologies which do not create serious noise problems.

In contrast, noise levels are a significant consideration in the case of wind power stations. The sources of noise are the gears and the generator, but also the airstream on the rotor blades. Gears and generator can be encapsulated and suspended inside in such a way that no vibrations are transmitted to the pod. This will muffle most of the noises. Another way is to construct gearless windmills. The current state of the art allows for the construction of wind power stations free of any problems of mechanically produced noises [15]. However, reducing the noise emitted from the rotors means making compromises with regard to the optimal form and stability of plant components. At present noise reductions are achieved through relatively low blade-tip rotation speeds. In up-to-date plants with an installed capacity of 500 kilowatts noise emission levels measured at source range from 98 to 101 dB (A).

In Germany, noise pollution from technical plants is regulated by means of the "Technical Guidelines Noise" (TA Lärm) in the Federal Emissions Protection Law. According to these regulations there must be a minimum distance of 400 metres between individual wind power installations of the 500 kilowatt class and primary residential areas. In the case of a wind park with several installations, the minimum permitted distance to the nearest houses is 500 metres. These spatial restrictions ensure protection against possible damage to human health through the effects of sustained noise. Animals familiriaze to the noise of windmills.

Aesthetic objections and accusations of **visual pollution** are counterarguments mainly used today against the utilisation of wind energy. But another target for such criticism is solar architecture. Some of its characteristic features in house construction do not meet with the approval of all building authorities, so that building permission is often difficult, and sometimes impossible to get. The reason given is that the continuity of the cityscape must be preserved - an argument which may oc-

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[14] Hall, D. O.; Rosillo-Calle, F.; Williams, R. H. und Woods, J. : Biomass for Energy: Supply Prospects in Renewable Energy Sources for Fuels and Electricity; edited by Johansson et al.; Earthscan Publication Ltd., London 1993

[15] Keuper, A. : Wind energy is active environmental protection and nature conservation; DEWI Magazine No. 2, Journal of the German Insitute for Wind Energy (Deutsche Windenergie-Institut), Wilhelmshaven, February 1993

casionally be understandable from an aesthetic perspective, but in terms of climate conservation is highly questionable. Aesthetic considerations are often also an obstacle to the spread of the decentralised installation of photovoltaic and solar collectors. The extent to which wind energy plants or other technical installlations visually "pollute" a landscape depends very much on the subjective opinion of the beholder. Commissioned by the Administrative District of Wesermarsch, an interdisciplinary study into landscape aesthetics of wind energy plants was conducted from both a sociological and a landscape-planning perspective. The findings of this study, and others, was that both tourists and local residents were basically open to the idea of harnessing regenerative energy sources. But local residents and regional tourists tended to make more of a political issue out of alterations to their landscape than did long-distance holidaymakers. Regional tourists, for example, consider the open Wesermarsch and the coastal landscapes as characteristic for the region and would view visual changes to it, e.g. through wind energy plants, as eyesores. In contrast, holidaymakers who travel long distances to visit coastal regions have already grown used to the sight of wind power plants and would even miss them if they were not there. Instead, they tend to view the enormous hotel complexes near the beaches as the real crimes against nature. These are the fronts between the aesthetic sensitivities of locals and strangers. The study indicates clearly how subjective such evaluations are and how impossible it is to find a decisive answer to the question. Cases of wind park planning where the local community was involved and kept sufficiently informed from the very start suggest how best to avoid such irrational discussions [16].

Many critics argue against the utilisation of renewable energies because of their large **land area requirements**. The basis of this argumentation is the low energy density of renewable energy sources compared to conventional sources. The conclusion drawn is that provision of energy through renewable sources will require more land surface area. From an environmental perspective, however, the low energy density of these renewable sources is an advantage. Generally speaking, the more energy a single technology can provide from within a limited space, the higher the risk of ecological damage to that space. Energy density is in fact a measurement of the capacity of an energy transformation technology to do damage to a location. But it is true that because of their low energy densities, renewable energy technologies require greater areas for the collection and concentration of energy than some conventional technologies.

Land requirements for various technologies have been assessed in several scientific studies [17]. For the production of one gigawatt hour of electricity for thirty years a coal-fired power station needs a surface area (including mines, overburden tips, etc.) of 3642 square metres, photovoltaic installations

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[16] a) Hasse, J.; Schwahn, Ch. : Wind power and landscape aesthetics: Wesermarsch; Interdisciplinary study in three parts, commissioned by the Administrative Districts Wesermarsch, Bunderhee and Göttingen; 1992
b) N.I.T. :Wind energy and tourism (pilot study): Attitudes of holidaymakers to wind energy exploitation; Institute for tourism and spa research in northern Europe (Institut für Tourismus- und Bäderforschung in Nordeuropa GmbH), Kiel, October 1991

[17] Worldwatch Institute, based on Meridian Corporation, »Energy System Emission and Material Requirements«, prepared for U.S. Department of Energy, 1989; Paul Gipe, »Wind Energy Comes of Age«, Gipe & Assoc., 1990, and other sources

(on fields) 3237 square metres, wind converters 1335 square metres and geothermic power stations 404 square metres. At the wind park »Nordfriesland« in Friedrich-Wilhelm-Lübke-Koog in Schleswig-Holstein, 50 wind converters with a total output of 12 000 kilowatts are installed on an area of 650 square metres - and these are older, lower performance machines (operational start up 1991). With the 600 and 500 kilowatt wind energy plants being built today the power yield from this area would be significantly increased.

Photovoltaic power is often used to illustrate what enormous areas of land would have to be sealed over by power stations if society's electricity requirements were to be fulfilled by solar power. But why build installations on open fields when their technology is predestined to be applied decentrally? There are more than enough existing structures where solar arrays could be installed, for example, on roofs, on facades, or on noise protection walls. There is absolutely no need for any further land surfaces to be encapsulated for the sake of this technology, nor for solar architecture or the decentralised utilisation of the sun's heat. The surface area requirements of wind energy installations are minimal, namely the size of the foundations of a windmill and its transformer station. Beneath a windmill any form of normal commercial activity for which the noise factor is of no relevance can continue. Already operative wind parks show that a surface area of only 0.05 square metres is required to produce one kilowatt of power. Solar-thermic power stations in the USA with a total output of 350 megawatt take up altogether 750 hectares of land surface, corresponding to a specific area requirement of about 20 square metres per kilowatt of operative output [18].

The really interesting question is how much surface area is potentially available for the cultivation of biomass, remembering that only sustainable cultivation methods can be considered as viable. Within the framework of the the study »Sustainable Europe« we devoted our attention, among other things, to the environmental medium soil, and drew up a scenario for the year 2010 from the perspective of sustainable forms of land exploitation. A central condition of this scenario was the sustainable provision of the population with sufficient healthy nutrition. We also proposed further demands and made a range of assumptions concerning the patterns of use of the land surface areas of the European Union. In the study we endorsed, for example, the demand of the "International Union for the Conservation of Nature" (IUCN) that ten percent of the land area be returned to nature and agricultural exploitation in these areas be forbidden [19]. Furthermore we took the demand for an agricultural exploitation of arable and pasture lands according to the criteria of ecological farming methods into consideration when calculating the nutritional requirements per capita of the population, which we limited to amounts corresponding to the recommendations of the German Society for Nutrition. Even if all requirements of foodstuffs, animal fodder and additional agricultural products (e.g. cotton, diverse fruits, coffee, cocoa, tea, tobacco, etc.) were produced on the land area within the frontiers of the EU, there would still be an area of arable and pasture land left of

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[18] Flavin, C.; Lenssen, N. : Powering the Future: Blueprint for a Sustainable Electricity Industry, World Watch Paper no. 119; June 1994

[19] International Union for the Conservation of Nature : Our responsibility for the Earth; Gland (Switzerland), October 1991

about 160 000 square kilometres for the cultivation of energy crops. First estimates suggest that about ten percent of current primary energy requirements of the European Union could be yielded by this area, with further energy sources to be found in residual materials from forestry and agriculture [20].

A recent calculations of the available roof areas of Europe which is oriented favourably enough to be exploited as locations for solar technologies counts 4800 square kilometers. Surface areas of building facades, which could be used, for example, for photovoltaic arrays if they face in the right direction amount to an area of 2500 square kilometers [21]. Using the roofs and facades of German buildings about 22 percent of present net electricity production of Germany could be achieved on these surfaces, and they are available for use without another single square metre having to be concreted over. They can be directly utilised to catch solar energy, as a sort of secondary function.

In southern Europe 19 500 square kilometres are available for solar-thermic power stations, according to estimates of the German Research Institute for Aeronautics and Astronautics (Deutschen Forschungsanstalt für Luft- und Raumfahrt - DLR). These 19 500 square kilometres could yield 75 percent of the electricity requirements of the EU– on areas which are available for use and are well linked to the necessary infrastructure. These figures clearly indicate that surface area for renewable energies is not a problem.

As to the exploitation of biomass, the question is often raised of the enormous **transport intensity** involved. But, assuming that a maximum of ten percent of the surrounding agricultural area is dedicated to energy crop cultivation, a biomass power station can maintain a constant output in the region of ten megawatts using the raw material yields from a surrounding area with a radius of only about seven kilometres. The exact area requirement would, of course, vary according to fertility of soil and efficiency of power production.

Renewable energies also have manifold **positive effects** on the environment. Apart from the potential increase in biodiversity through appropriate biomass crop policies, and apart from the potential for restoration of degraded soils, the use of renewable energy technologies offers many other advantages, for example with regard to waste processing. For example, it is possible to purify organically polluted waste water using water plants (e.g. hyacinth), and these plants could then be exploited for their energy potential. In the agricultural sector, the use as biomass of livestock farming residues (slurry, manure, slaughterhouse waste) reduces the load on the soils, since such residues no longer need to be spread onto the fields, produces energy and, in addition, allows energy-intensive chemical fertilisers to be replaced by the bio-fertilisers which are produced as by-products in the combustion of biomass, and which are available all year round.

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[20] Lehmann, H.; Reetz, T.: Sustainable Land use in the European Union; Towards a Sustainable Europe - The Study -, December 1994

[21] Drees B., Lehmann H., Reetz T. : not yet published study by the author and colleges.

Renewable energy technologies are very highly diversified and decentralized. It is important to constantly bear in mind that the use of renewable energies, regardless which particular technology, produces no carbon dioxide emissions, leaves no radioactive isotopes to be disposed of, and, to our present knowledge, harbours no global or transgenerational dangers. The known problems can all be satisfactorily minimised through appropriate measures during the application of the technologies. Renewable technologies have an inexhaustible and sufficiently high potential of resources that we do not need to worry about their range.

A sustainable energy system in the future will have to be based on three main funding principles: The use of renewable energy technologies; the efficient explotation of available limited energy resources so that the greatest benefit for the welfare we desire is achieved from what we take from nature; and, lastly, a conscious consensus on the limits of consumerism, which, at the end of the day could affect the lives of millions of individuals.

Economic growth and renewable energy technologies.

In the industrialised countries, shifting priorities to renewable energy sources will create economic growth. Renewable energy resources are indigenous and abundantly available. Using them decreases the necessity to import energy carriers. Less importation of energy carriers helps to balance the export/import payments of Europe and lower its dependency on foreign suppliers. In 1990 the EU spent 60 thousand million ECU abroad for oil imports alone. In the same period of time, Germany paid approximately 50 thousand million DM for imported energy sources. The exploitation of domestic sources through renewable energy technologies would allow an increasing proportion of this money to stay in Europe creating jobs and greater welfare inside the community.

Current estimates of exactly how many new jobs would be created range widely. The increase in labour requirements follows from the decentralised character of energy production using renewable sources. For wind energy, direct employment per kWh is estimated to be three to five times that of conventional energy, at comparable energy costs. For photovoltaic energy, it is currently 2.5 times higher, but this factor will decrease through mass production. Findings of the Worldwatch-Institute indicate that every thousand gigawatt hours per year produced through atomic power creates 100 jobs, through coal-fired power 116, through solar-thermic power 248 and through wind 542.

The amount of created jobs depends on the proportion of energy requirements covered through the use of renewable energy sources. The current unambitious target of 8% by the year 2005, as formulated in the ALTENER decision of 1993, will clearly produce less new employment than the easily achievable goal of 15% by the year 2010 as formulated in the "Action plan for Renewable Energy Sources in Europe" (Madrid 1994). This plan was elaborated by DGXVII in co-operation with European renewable energy experts. For Germany, recent calculations put the possible additional creation of employment in the order of half a million jobs if renewable energy potentials are used to a maximum level[22]. For the EU, with a possible production potential of 50% of its energy needs through renewable energies in the year 2020, several million jobs could be created[23]. The "International Network for Sustainable Energy" (INforSE) expects 0.6 to 1.3 million additional jobs to be created in the EU within the first ten years of a policy change towards renewable energies. If only about ten percent of EU electricity supplies were produced by means of biomass, at a price of 0.06 to 0.10 ECU per kWh , this would mean an additional turnover for rural regions and for the biomass-processing industries of between 11 000 and 19 000 million ECU per year. This possibility of an additional source of income which is dependable in the long-term would also reduce the need for subsidisation of the agricultural sector.

Renewable Energy Technologies are today already an important source of jobs in the countries of the European Union. The following figures show the state of the labour market in the year 1990 and developments so far in the field of solar-thermic energy technologies. The biggest producer within the EU in the year 1990 was Greece, with a current annual production rate of about 130 000 square metres. EU total production in 1990 amounted to 245 800 square metres. 500 companies manufactured, distributed and installed solar collectors in 1990, achieving an annual turnover of about 180 million ECU and employing about 3000 people[24]. Austria increased its production of solar collectors between 1989 and 1993 from 49 000 square meters to 148 000 square meters, and in Germany 215 000 square meters were produced in the year 1993[25], nearly as much as the total EU production in 1990 and five times more than the production level in Germany in 1990.

Not only in the field of solar thermic technologies have employment and installation rates increased dramatically in recent years. In 1990 in the EU 12 countries 484.8 MWp of installed electric production capacity through windmills were reported. By 1993 this had increased to 1054.4 MWp. By the end of 1994, a total of 2617 wind energy plants with an installed capacity of about 643 megawatts were operational in Germany alone [26] , a doubling of capacity in Germany within just one year. In 1995 the German wind energy branch expects a total turnover of 500 million ECU.

Last year just may well go down as the year in which the photovoltaic industry worldwide shifted gears and moved into a faster and much larger phase of growth for this decade. After four years of a slower growth-rate, energy production and installation of photovoltaic modules worldwide rose by 19% in 1994 to reach a new record high of 72.7 MWp. This is an estimated turnover of 650 Million ECU. PV module output worldwide has more than doubled since 1988. It is important to note that this record growth rate was charted in a year when much of the world was still caught in an

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[22] Mohr et.al.; Bochum 1995

[23] EUROSOLAR, The Potential of Renewable Energy in the EU; Bonn 1994

[24] TECSOL : Solar-thermic technology in Europe; EG Commission, French Agency for the ??? of Energy (Agence Francaise pour la Maitrise de l'Energie), Brussels 1992

[25] Deutscher Fachverbad Solarenergie, 1994

[26] Keuper, Armin: personal communication, DEWI Wilhelmshaven 1995

economic downswing[27]. Total shipments for 1995 could reach an installed capacity equivalent to 90 MWp. This represents an increase in PV manufacturing by 20%. Some manufacturers report module shipment higher than 20%, as well as delays in shipment because manufacturing capacity can't keep up with the demand.

Country	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
USA	7.7	7.1	8.7	11.3	14.1	14.8	16.2	17.9	21.0	25.6
Japan	10.3	12.6	13.2	12.8	14.2	16.8	18.7	18.3	17.0	19.5
Europe	3.4	4.0	4.5	6.7	7.9	10.2	13.0	16.0	17.0	21.6
Rest	1.4	2.3	2.8	3.0	4.0	4.7	6.0	6.0	6.0	6.0
World	22.8	26.0	29.2	33.8	40.2	46.5	54.0	58.2	61.0	72.7

World wide module shipment (MW)[28]

Jobs and economic growth is not only generated by the internal use of renewable energy sources. The World Bank estimates that over the next decade, the developing countries will require 100 billion $ annually in capital investments to address the explosive growth in their energy needs. If renewable energy technologies covered only a fifth of these projected annual energy investments, which is a very cautious estimation, this would represent 20 billion $ in annual technology sales for the next decade. It is estimated that out of the current world population of 5.5 billion 2 billion is not connected to an electric grid and 1 billion has no electricity at al. Particularly with respect to the decentralized energy supply of this rural regions in developing countries, renewable energy technologies are in general economic superior to their conventional alternatives.

These export and trade opportunities have already been recognized by other regions of the world. In recent years the USA built up a network for a strategic export-offensive in the field of renewable energy technologies. Main objective is the export of these technologies to Latin America and the rapidly growing economies in China, India an Southeast Asia. Supported by the new founded organisations "US Export Council for Renewable Energy" (US/ECRE) and "Committee on Renewable Energy Commerce and Trade" (CORECT) the US department of Energy expects the installation of 8000 MW worldwide of US solar electric technologies in the next 5 years. Recent succeses like the "Mexico-US Renewable Energy Program", the Brazilian rural electrification

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[27] PV Insider's Report, February 1995

[28] Sources: Maycock, P.D.: International photovoltaic markets, developments and trends; 10th European Photovoltaic Solar Energy Conference, 8-12 April 1991 Lisbon, Portugal and Photovoltaic Insider's Report, February 1994 and 1995

program and several trade missions to India and China show that this goal can be reached. Two trade missions to China and India in February 1995 alone resulted in 1 350 million $ and 630 million $ investment intentions. One Example : India will purchase 300 MW wind capacity from US companies as a beginning of planned installations of 20 000 MW. This windmill installation goal corresponds to an estimated value of 15 000 million ECU technology investments in the next decade. Japan promotes its selling in developing countries by providing almost half of the total amount of developing aid funds in favour of renewable energies and its "Overseas Economic Cooperation Fund", that grants long-term soft loans. These regions (Unites States and Japan) are taking advantage of the fact that although Europe still holds the leading position in photovoltaic and windmills research, it is harmpered by a lack of product placement and export initiatives. It is easier to sell renewable energy technolgies in the developing countries having 9000 MW of installed electric production capacity and a concerted export strategy including financing like it is in the case of the USA or in the case of Japan having the "New-Sunshine-Program" which is funded with 558 million $ in 1995 and a 65 000 Photovoltaic-Roofs-Program.

Europe at the moment still holding the leading position in some of the renewable energy technologies will fall back, if this technologies are only run in laboratories or in some demonstration sites. The big succes of wind energy was stimulated on the one side by the market penetration of windmills in Europe, the mass production of windmills and on the other side research and development helped to decrease the costs and to increase the installed capacity of the windmills. Future export success will depend on several factors, first the quality stimulated by intensive research. Secondly demonstrating confidence in the renewable energies by using these technologies in the own energy system. And a concerted export strategy including information, support by official agencies and financing schemes. To maintain a leading position (e.g. in photovoltaic and wind technologies), and to gain a leading position in other fields of renewable energy technologies, Europe will need to achieve a concerted promotion of these technologies through research, demonstration, dissemination and through market penetration in Europe.

Market penetration of renewable energy technologies in Europe

Market penetration of renewable energy technologies will generate the above discussed advantages. Before turning attention to the steps needed to realize this introduction of renewable energy technologies (e.g. taxation, internal energy market) some comments about obstacles blocking the path to the goal of using a high amount of renewable energies in Europe.

To fully realise the potential of renewable energy technologies and to achieve increased efficiency, it will be necessary to think in terms of decentralised, regionally oriented energy supply concepts. Equal priority will be given to the most efficient technical exploitation of renewable energy sources and to the most effective local specialisation of available resources: wind power at the coasts, biomass in rural areas, photovoltaic arrays, and passive and active use of heat exchange technology, in built-up areas. The redistribution of regional surplusses by means of a superregional network is another feature of this future energy supply structure. The network may be a decentrally fed electricity grid or gas network. Transportation of high-grade biomass may be another possible form of energy surplus redistribution. A superregional network could also function as a store for energy surplusses, using biogas or electrically produced hydrogen as a storage medium. Only the power requirements still not covered by regional production and redistribution systems will then be generated in centralised, large-scale power stations. These centralised power plants may be hydropower, biomass or solar-thermic installations. Power plants which use fuels produced in other regions, like hydrogen or biogas, are parts of the system.

The current centralised energy supply structure is one of the largest obstacle in the way of the wider use of regenerative energy sources. Billions of ECU of investments by the major energy supply companies in the existing structure, the construction of further large power station blocks and the corresponding distribution network, have not only tied up large amounts of private and state money, but are also blocking the construction of a decentralised, more flexible form of energy supply. The incompatibility of the current distribution system can be observed in that regions of Europe where windmills start to play a sigificant role. To be able to handle the electricity fed in the net by decentralized windmill producers, utilities have to restructure and to reinforce parts of the net. Standarts about the stability of frequence and voltage of the net, coming from former times make it harder to manage a system with a high degree of intermittend sources (e.g. photovoltaic and wind). Unfortunately the necessity of restructuring the net, of the changes needed in standarts and management are not yet realized, have not yet started. Even worse, some of the parties involved currently in the energy market will in the long term be the losers if a decentralised energy system is introduced. They use their influence on politics or in the form of anti-publicity to prevent the introduction of renewable energy technologies. If the centralised concept, plans and actions of the main players in the energy sector does not change, the installation of decentral, renewable energy system will continue to be restricted to niche applications. Foiirtunately a increasing number of energy suppliers, service companies and plant manufacturers are seriously investigating the introduction of renewable energy technolgies and looking for a part for themselves to play in such a energy market.

The high prices of energy from renewables is the oldest argument against their use. The table »Electricity and heat production prices« summarises actual prices of renewable energy technologies.The table shows the price of electricity production through a range of different technologies.

Some technologies are close to the break-even point or have even crossed it, and achieved commercial competitiveness with conventional technologies. Solar-thermic heating for swimming pools, for example, is already cheaper than natural gas heating. Other technologies, however, are still far away from achieving economic viability. There are several reasons for this. The lack of mass production is one important reason for the present high prices of, for example, photovoltaic technology. In the production of photovoltaic modules a lot is still done by hand. This intensifies the vicious circle of high prices because of absence of mass production and absence of mass production because of low sales because of high prices. This vicious circle must be broken before a technology can gain greater share of the market.

Electricity		Minimum (ECU/100)	Maximum (ECU/100)
Biomass	Wood (1)	6.5	8
	Straw (1)	6.5	8
	Biogas (2)	13	24
Wind	windparks (5) (high average windspeed)	5.5	7
	single windmill (6) (low average windspeed)	14	36
Hydropower	(9)	2	40
Solarthermal	SEGS System (8) with different portion of additional fossil heating	8	16
Photovoltaic	(7)	33	100
Heat			
Biomass	Wood (1)	4.5	7
	Straw (1)	4.5	7
	Biogas (2)	3.5	8
Solarthermal	Heating of water on roofs (3)	14	36
	District heating (4)	7	15
	Swimming pool heating (4)	2.5	4

Table : Electricity and heat production prices for renewable energies
(1) Landtechnik Weihenstefan 1994, Landesenergieverband Steiermark 1994
(2) J. Nitsch, DLR 1993; (3) Öko Institut and own calculations, 1992 - values for mid-Europe;
(4) E. Hahne 1993 - values for mid-Europe; (5) B. M. Pedersen 1993;
(6) Ministry of Economy, State of NRW, 1993; (7) W. Hoffmann 1994 and own calculations - low price for centralised system in Toledo, higher price for roof installed system in Germany;
(8) R. Ahringhoff 1993; (9) E. Wagner, 1994
production cost of electricity from conventional technologies approx. 5.5 ECU/100 and heat from conventional technologies approx. 4 ECU/100.

Another way to establish a market for renewable energy technologies is to create **equal opportunities**. Conventional technologies like fossil fuels or nuclear plants have been subsidised during recent decades. Starting with very high expenditures on research, development and demonstration - between 1986 and 1990 the USA, UK, Germany, Italy and Japan spent 2039.5 million $ for research into all renewable energy technologies (wind, PV, geothermal, solarthermal, biomass etc.). In the same period of time, nuclear fusion alone received 4485.6 million $. At the beginning of this decade, the Community spent only one fifth of its research funding on energy related research for renewables and efficiency technologies. Even in the running 4th Framework Programme there is only a slight change towards renewable energy technologies. The national research budget has not increased the funding of renewable energy technologies to a sufficcient level in recent years. It is not only this lack of adequate funding which has reduced the chances for the renewable energy technologies to penetrate the market. Tax privileges of various forms, differing from country to country , favour conventional technologies over renewables and energy efficient technologies. Such tax privileges are incompatible with the goal of an environmental energy system and are no longer justified.

The so-called "**external costs**" involved in the exploitation of conventional energy sources are not included in the price per kilowatt hour of electricity or heat produced from these sources. The prices do not tell the ecological truth, i.e. the external costs, or damage caused through production, are not reflected in them. If the social (external) costs of electricity production based on fossil fuels is added, the result is, according to a study conducted by Olaf Hohmeyer, an additional cost of at least 2.1 to 4.7 ECU/100 per kilowatt hour for fossil fuels, and for atomic fuels from 5.3 to 11 ECU/100. Compared to this, the exploitation of renewable energies has a net utility value to society (i.e. in avoided costs) of between 3.1 and 6.3 ECU/100 (wind energy) or 3.7 and 8.9 ECU/100 (photovoltaic energy). Since the policy in that study was always to take the lowest estimated values wherever the data was incomplete or uncertain, the total social value of renewable energies is probably a lot higher than this [29].

One possible instrument would be the inclusion of the costs of environmental damage through energy production in the energy prices by means of an **ecological taxation** reform or through an energy or carbon dioxide-tax. The following is a description of various taxation proposals and their advantages and disadvantages.

According to a resolution of the German government, carbon dioxide emissions in the Federal Republic are to be reduced, by the year 2005, by 25% as against 1987 levels. In this endeavour, priority is to be given to market economy-oriented instruments for the realisation of this goal. In order to exploit all possible paths towards effective CO2 reduction, the introduction of a climate protection tax (carbon dioxide tax), an energy tax, or a combined carbon dioxide/Energy tax is envisaged (but not yet realized). This does not imply an expectation that the targeted reduction of 25% will be achieved through such taxation alone. On the contrary, this concept of a levy is just one component in a whole bundle of measure to reduce carbon dioxide. The main parameters of the proposed charges will be the carbon dioxide emissions released into the atmosphere, including a

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[29] Hohmeyer, Olaf: The social costs of energy consumption, Springer-Verlag, Berlin 1989

correction factor for methane emissions, and the annual efficiency rate of firing installations. The basic projection is of a taxation rate of DM 10,- (5.3 ECU) per ton of carbon dioxide, graduated according to specific efficiency rate.

Revenues from this fiscal measure would be appropriated for the financing of environmental protection measures, particularly for climate protection (carbon dioxide reduction measures) and would be primarily deployed in the new Länder. A study of future developments in the power producing industry commissioned by the Federal Ministry of Economics and conducted by the Prognos AG group several years ago provided the following estimates for the year 2005. Assuming a crude oil price of $20 a barrel and internationally controlled increases in the costs of fossil fuels passed on in the form of a 15% rise in end-consumer prices, a slight increase in primary energy consumption until 1995 will be followed by a fall to 384 million tons of coal equivalent in the year 2005, which would be below 1980 levels. This would achieve a drop in carbon dioxide emissions by four percent by the year 2005. In an alternative scenario based on a crude oil price of $25 a barrel and a doubling of duties on fossil fuels, Prognos calculates a possible reduction of carbon dioxide emissions by 10.5 percent.[30]

In 1992, the EU-Commission presented its draft proposals for the introduction of a tax on carbon dioxide emissions and on energy. This EU draft policy guideline is a central component of Community strategy for the achievement of lower carbon dioxide emissions and greater energy efficiency. To attain the goal of stabilising carbon dioxid emissions in the Community by the year 2000 at 1990 levels, it will be necessary, in the Commission's view, to introduce, among other a carbon dioxide/Energy tax. The draft guideline envisages, among other things, the harmonised introduction throughout the European Community of a carbon dioxide/Energy tax based 50% on the energy content and 50% on the carbon content of the fuels being used, with mineral oil taken as the reference quantity. Taxation rates will be raised in annual stages. Regenerative energies will be exempt from the levy. The constituent fiscal facts will be the extraction, production or importation of fuels, and involvement in such taxable transactions will be the criteria for tax liability. The basis of tax assessment for the energy-related component of the levy will be the energy content of the particular fuel; for the carbon dioxid emissions-related component, the amount of CO2 created through oxygen surplus during the combustion of the taxable energy products. Heat and electricity generated from fossil fuels will not to be taxed directly, but via taxation of the primary energies employed to produce them (input). However, in the case of electrical power, the energy-related component of the levy will be fixed, regardless of the fuel used, in relation to the amounts of current produced as measured in megawatt hours (output). The fiscal rates will be fixed in ECUs for all taxable products on the basis of $3 per barrel of mineral oil equivalent for the year 1995, then increased annually by $1 per barrel mineral oil equivalent until a ceiling of $10 per barrel mineral oil equivalent is reached.

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[30] Federal Ministry of Economics of FRG, "Carbon dioxide Reduction", BMWi Studienreihe 72

Enterprises with high levels of energy consumption which would suffer severe disadvantages as a result of increases in competitive imports from non-OECD countries which have not implemented parallel measures will, under certain circumstances, be granted tax privileges. Enterprises which actively invest in measures to rationalise energy consumption or limit carbon dioxid emissions will also qualify for fiscal incentives in the form of reduced tax bills or tax refunds, and possibly even in the form of tax credits or equivalent eligibility for concessions in following years related to the costs of investments made ("compensation").

According to a study by the EC-Commission, these taxation proposals would result in CO2 emissions in the year 2000 being held at levels only 7.1%, rather than 10.9%, higher than those of 1990. Considerable differences of opinion still prevail between EU member states with regard to the introduction of a carbon dioxide/Energy tax throughout the Community. There is great contention about details of tax relief and exemption, about the conditions required to ensure fair distribution of the fiscal burden when the legislation is implemented, and about the potential effects on Europe's competitiveness on the international market.

A third type of proposal is put forward by the DIW or by the "Society for the Promotion of Ecological Tax Reforms" (Förderverein ökologischer Steuerreform - FÖS). At the core of the DIW proposal is a progressively increasing energy tax on fossil fuels and electricity. This is conceived of as a bulk tax also encompassing the use of oil and gas as raw materials in non-energy production sectors. The fuels would be taxed at a standard rate per unit of energy content. This rate would gradually increase over a period of time. The tax rate would apply to all fuels according to a hypothetical basic price of 4.7 ECU per gigajoule, equivalent to 9.7 ECU per ton of coal equivalent. The charges would be levied in addition to already existing taxation of the various fuels. This would lead, in the case of oil and gas, to a double tax burden because of the already existing duty on mineral oil. The tax rate would increase annually by 7% in real terms, i.e. by a nominal 10%.

After a period of five years, the tax rate would have already reached a level of 56 ECU per ton of coal equivalent. After ten years it would have more than doubled itself to 134 ECU, and, finally, in the year 2010, at the end of the time period considered, would have reached 244 ECU per ton of coal equivalent. According to the DIW proposal, the energy tax revenues would not increase total state revenues, but be earmarked for the reduction of labour costs for both public and private sectors and of the financial burden on private households. This would be achieved by reducing public and private employers' shares of social security contributions, and by introducing a bonus system for private households,. The proportional spending of the revenues from energy taxation on these reductions is envisaged as 71% for compensation of tax burdens on enterprises and the state, and 29% for compensation of tax burdens on private households. However, this feedback concept would not included the value added tax levied on the energy tax bills.

The differences between the DIW model and the FÖS model are that in the FÖS model a smaller (five instead of seven percent) increase in the costs of energy consumption fixed for a period of only five years is envisaged, that flanking eco-fiscal measures (like a compensation concept benefitting industry in the form of a reduction of employer's contributions to unemployment insurance) are proposed, and that the DIW suggestion of an "eco-bonus" is rejected as an "unsystematic, impractical and superfluous addition to existing socio-political instruments".

Regarding the individual forms of energy, the DIW model foresees changes in the costs of energy consumption for private households over a ten year period as follows: increases in regular petrol prices by 24%, increases in domestic electricity costs by 46% and increases in light fuel oil for household heating by 73%. According to their model, Industrial energy consumption costs would increase in the same time period by 135% for heavy fuel oil, 105% for natural gas, and 95% for electricity.

The overall economic returns from this taxation concept can be calculated from the individual tax rates and energy consumption levels. In an evaluation of the overall economic advantages of this taxation scenario, the DIW draws the following positive conclusions: economic growth and foreign trade would not be impaired; the international competitiveness of production enterprises would not be negatively influenced; from an overall economic perspective as many as a half million new jobs (in Germany) could be created during the ten year period; primary energy consumption would fall by the year 2010 by almost 24% against 1987 levels, and carbon dioxide emissions by almost 25%.

Criticism of the energy tax concept centre on the following arguments: fiscal-procedural questions still need to be answered relating to the introduction of a general energy tax, especially with regard to the bases for tax assessment, to the treatment of the use of primary energy raw materials in non-energy production sectors, and to foreign trade. In addition, there is a significant insecurity factor concerning the effect of the measure, since it is difficult to make accurate prognoses of the reactions of consumers to such a tax. The most important argument forwarded, that the fiscal measures would negatively influence economic competitiveness on the international market, can be countered through compensatory measures such as relief for industry and trade through the reduction of ancillary wage costs.

To summarise, the arguments for the introduction of a duty levied on energy consumption are as follows: internalisation of external, environmentally damaging effects; reduction of energy consumption and carbon dioxid emission levels; innovation incentives for industry and energy producers; positive effects on the labour market; reduction of labour costs and last but not least the promotion of renewable energy production.

Of course such a taxation strategy will take some time. In addition, in the short run, improved **feed–in rates** for electricity produced from renewable energy sources and subsidies for the production of heat can be a powerful incemtive for the market introduction of these technolgies. Premium payments, such as in Germany (Stromeinspeisegesetz) or in the UK (NFFO), should be part of a harmonized European legislation for granting favourable minimum feed-in rates for renewables. A common rule should be considered granting renewables preferential treatment as regards access to the electricity grid and above market tariffs. The price paid has to be at least equal to the average price paid by grid operators for electricity from conventional sources. Higher prices could be paid in cases the external benefit of the renewables are considerable. Harmonized minimum rates can be introduced for countries with monopolized energy structure. A time or system-load dependant rate is also thinkable. For certain technologies, to promote them until they have reached a certain market penetration, full and fair feed-in rates, as granted by some German local communities, should be part of such a regulation.

This legislation should be part of the planned **Internal Energy Market** for Europe. A future Internal Energy Market oriented on environmental and employment goals should be a instrument to introduce renewables and efficiency technologies in the market and a instrument to balance the historical grown differences and inparities between the conventional energy technolgies and the future energy technologies. To achieve this goal a harmonized carbon dioxide/Energy tax (see above), the unbundling of the various functions of energy utilities, a modified Third Party Access and renewable energy fed-in rates (see above) have to be part of this Internal Energy market. Until today, utilities in most Member States have repeadetly taken advantage of their monopoly position in both production and transmission of energy, mostly discriminating energy efficiency technologies, small auto producers (e.g. Cogeneration) and renewable energy technologies. Unbundling the production and distributon of electricity will correct market distortions and unfair traetment of smaller producers. Without such an unbundling only large scale producers from conventional technologies may benefit from Third Party Access. A modified TPA will offer preferential, in the first time even exclusiv TPA for small scale producers (e.g. cogeneration plants and renewables). This will initiate a trend towards a decentralized energy system and will help to overcome with the above discussed obstacle of the today centralized system.

Executive Summary

The idea of sustainable development is based on a recognition of the equal rights of both present and future generations, in all continents, to the fulfilment of their basic needs and requirements. In order to meet these aspirations to a better life in a spirit of equal rights, an environment must be maintained in which all human beings can live naturally. Science today still knows very little about the Earth and its subsystems, and has hardly even begun to investigate some parts of them. At this stage in history, and perhaps for all time to come, our actions must be guided by this recognition of how little we know about our Earth's "survival" system and its susceptability. As a precautionary measure, we should therefore attempt to minimise anthropogenic effects on this system, and thus prevent as far as possible any negative consequences. This precautionary principle must constitute the main guideline for all human activity if sustainable development is to be our primary aim.

Under this principle, the operation of a sustainable energy technology should involve neither direct nor indirect effects which may hamper the development of future generations. Material flows, including those of substances which occur naturally and are not harmful, should be as small as possible. No known global inter- or intragenerational risks should involve neither direct nor indirect effects which may impede the development of future generations. Energy technologies must not be based on finite resources, since these will be exhausted sooner or later and will therefore not be available to future generations. All these conditions are met only in part, if at all, by energy technologies currently in use, and it is unlikely that any single technology will ever completely fulfill them. They do, however, provide a fundamental yardstick for decision-making with regard to technologies or combinations of technologies now being considered for use in the energy system of the future.

By checking the extent to which different energy technologies fulfil these conditions, we can arrive at a priority list of the technologies which qualifiy to be a part of a sustainable energy system. Fossil fuels carry the risk of a climate change. Nuclear technologies (fission and fusion) have the danger of dissipative losses of radionuclides. Such dissipative losses will have a severe impact with unknown hazards for microflora and microfauna. At the moment we are using up fossil fuels at a rate very much higher than they can be regenerated, and we will have exhausted them within the next century. Fission also has a limited amount of resources.

Renewable energy technologies are very highly diversified and decentralized. It is important to constantly bear in mind that the use of renewable energies, regardless which particular technology is employed, produces no carbon dioxide emissions, leaves no radioactive isotopes to be disposed of, and, to our present knowledge, harbours no global or transgenerational dangers. The known problems can all be satisfactorily minimised through appropriate measures during the application of the technologies. Renewable technologies have an inexhaustible and sufficiently high potential of resources so that we do not need to worry about their range.

A sustainable energy system in the future will have to be based on three main funding principles: The use of renewable energy technologies; the efficient explotation of available limited energy resources so that the greatest benefit for the welfare we desire is achieved from what we take from nature; and, lastly, a conscious consensus on the limits of consumerism, which, at the end of the day could affect the lives of millions of individuals.

In the industrialised countries, shifting priorities to renewable energy sources will create economic growth. Renewable energy resources are indigenous and abundant by available energy resources. Using them decreases the necessity to import energy carriers. Less import of energy carriers helps to balance the export/import payments of Europe and lower its the dependency on foreign suppliers. The exploitation of domestic sources through renewable energy technologies would allow an increasing proportion of the money paid for external energy souces to stay in Europe creating jobs and greater welfare inside the Community. Current estimates of exactly how many new jobs would be created range widely. The amount of jobs created depends on the amount of renewable energy sources used.

For Germany, recent calculations put the possible additional creation of employment in the order of half a million jobs if renewable energy potentials are used to a maximum level. For the EU, with a possible production potential of 50% of its energy needs through renewable energies, several million jobs could be created. The "International Network for Sustainable Energy" expects 0.6 to 1.3 million additional jobs to be created in the EU within the first ten years of a policy change towards renewable energies. If only about ten percent of EU electricity supplies were produced by means of biomass, at a price of 0.06 to 0.10 ECU per kWh, this would mean an additional turnover for rural regions and for the biomass-processing industries of between 11 000 and 19 000 million ECU per year. This possibility of an additional source of income which is dependable in the long-term would also reduce the need for subsidisation of the agricultural sector. Renewable Energy Technologies are today already a important source of jobs in the countries of the European Union.

Jobs and economic growth is not only generated by the internal use of renewable energy sources. The World Bank estimates that over the next decade, the developing countries will require 100 billion $ annually in capital investments to address the explosive growth in their energy needs. If renewable energy technologies covered only a fifth of these projected annual energy investments, which is a very cautious estimation, this would represent 20 billion $ in annual technology sales for the next decade. These export and trade opportunities have already been recognized by other regions of the world. These regions (Unites States and Japan) are taking advantage of the fact that although Europe still holds the leading position in photovoltaic and windmills research, it is harmpered by a lack of product placement and export initiatives.

To maintain a leading position (e.g. in photovoltaic and wind technologies), and to gain a leading position in other fields of renewable energy technologies, Europe will need to achieve a concerted promotion of these technolgies through research, demonstration, dissemination and through product placement in Europe.

Market penetration of renewable energy technologies will generate the advantages discussed above. To fully realise the potential of renewable energy technologies and to achieve increased efficiency, it will be necessary to think in terms of decentralised, regionally oriented energy supply concepts.

The high prices of energy from renewables is the oldest argument against their use. But some technologies are close to the break-even point or have even crossed it, and achieved commercial competitiveness with conventional technologies. Other technologies, however, are still far away from achieving economic viability. There are several reasons for this. The lack of mass production is one important reason for the present high prices of, for example, photovoltaic technology. In the production of photovoltaic modules a lot is still done by hand. This intensifies the vicious circle of high prices because of absence of mass production and absence of mass production because of low sales because of high prices.

Promotion of a product placement of renewable energy technologies means creating equal market opportunities. Resarch funds for conventional technologies, subsidies and tax privileges of various forms favour conventional technologies over renewables and energy efficcient technologies. Such tax privileges are incompatible with the goal of an environmental energy system and are no longer justified. One possible instrument to ensure equal opportunities would be the inclusion of the costs of environmental damage through energy production in the energy prices by means of an ecological taxation reform or through an energy or carbon dioxide-tax. Despite some criticism such a tax reform will have the following advantages : internalisation of external, environmentally damaging effects; reduction of energy consumption and carbon dioxid emission levels; innovation incentives for industry and energy producers; positive effects on the labour market; reduction of labour costs, and last but not least , the promotion of renewable energy production.

A future Internal Energy Market oriented to environmental and employment goals should be a instrument to introduce renewables and efficiency technologies into the market and an instrument to balance the historically established differences and inparities between conventional energy technologies and future energy technologies. To achieve this goal a harmonized carbon dioxide/Energy tax, the unbundling of the various functions of energy utilities, a preferential Third Party Access for renewables and renewable energy feed-in rates must be part of this Internal Energy market policy.