Renewables and environmental implications

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ABSTRACT

Man has always been using energy from renewable sources. Recently, however, new quality in the perception of energy problems has been created and a distinct progress in energy use of biomass, geothermics, sun, water and wind has been achieved. Why is it that today views are re-evaluated towards sustainable usage of all available energy potential (fossil fuels, renewable sources, nuclear power), with clearly and firmly determined goals for a systematic development and an increase of share of energy from renewable sources in primary energy production even up to 70-80% by 2050. The fact that issues of pro-ecologically orientated energy and fuels are presently given a global dimension results from several economic, social and, above all, environmental factors, of which the main ones are: (i) systematically growing demands for primary energy, which is closely connected with demographic changes and lifestyle, (ii) fossil fuels resources are limited, depletable and their supply and consumption are not balanced, and (iii) since technologies for energy conversion from renewable sources are known for being less efficient and more expensive compared to fossil fuels, it is necessary to develop new technologies, search for new solution and continuously introduce innovations. According to the International Energy Agency, the rate of present changes and development in technologies for energy utilization have distinctive traits of energy revolution although some claim that it is only evolution. Nevertheless, new political programs orientated on pro-environmental development of energy sector with significant share of energy from renewable sources proclaimed by the European Union, the United States and the United Nations support the idea of revolutionary changes.

Environmental paradoxes related to exploitation of renewable sources are discussed, including a question of disparity between environmental effects, clean energy fiction, the myth of cheap energy, apparent diversification of agricultural production and enhanced biodiversity. In reference to biofuels, wind turbines, hydropower plants as well as solar and geothermal facilities, their interference with environment is analyzed from the point of view of environment management and protection. It has been stated that energy from renewable sources has become a significant component in the structure of supply and consumption of useful energy. This energy is an equivalent of energy from fossil fuels that has a great potential of reducing greenhouse gases emission. At the same time, differences in technological advancement of energy conversion from renewable sources between countries may deepen the present disproportions and cause secondary degradation of valuable natural ecosystems. Thus, rationalization of activities in order to capture specific equilibrium between positive and negative consequences of utilization of energy from renewable sources is purposeful. Rational use of renewables together with providing for environmental requirements will facilitate sustainable energy development.

INTRODUCTION

Discussion on environmental consequences of renewables is always an attempt to find a balance between growing energy use and environment management and protection. On the one hand there are different energy sources, i.e. renewable in a sense that they may be renewed in a relatively short time, non-renewable which are also renewable but their consumption goes faster than the renewal. There is also a term of “alternative energy” which may be interpreted in many ways but usually it describes energy which is environmentally friendly. An alternative may be energy from hydropower plants, alternative may be simply a change of a conventional coal burner into biomass burner, alternative may be energy cogeneration instead of generating only electricity. On the other hand there is the environment with its elements like climate, ecosystems, landscapes, resources and other components.

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Both sides of the balance must be equalized by proper environmental management, i.e. a process of intentional changes of natural environment, which are intended for economic usage (for agricultural, tourist as well as for energy purposes) or to restore the ecological function of ecosystems and landscapes. The second criterion of the balance is environmental protection which is focused on the proper exploitation and use of natural resources and restoration of the components of natural environment. Besides this, all of it must be considered in terms of sustainable development and energy security.

The other common terms in the field of renewables are green and clean energy. The different colours taken, even if conventional, are connected to greenhouse gases (GHG) emissions including carbon dioxide (CO_2), nitrogen oxides, sulphur compounds, and others. In general, green colour is always restricted to renewable sources of water, sun, wind, geothermal or biomass as well as to environmentally friendly processes of their conversion to different forms of energy. It should be noted that also coal, even if black or brown, may be green, it means it may be the source of clean energy when proper technologies like CCS (carbon capture and storage) may significantly reduce GHG emission.

The objective of the paper is to discuss some of environmental consequences of renewable energy use in the context of global energy policy, environmental paradoxes related to exploitation of renewable sources and chosen environmental effects connected with use of biofuels and wind-, solar-, and geothermal energy.

ENERGY RESOURCES – GLOBAL CONTEXT

Man has always been using energy from renewable sources. In recent times, however, a new awareness in the perception of energy problems has been created and distinct progress in energy use of biomass, geothermics, sun, water and wind has been achieved. Why is it that today views have been re-evaluated towards sustainable usage of all available energy potential (fossil fuels, renewable sources, nuclear power), with clearly and firmly determined goals for a systematic development and an increase of share of energy from renewable sources in primary energy production even up to 70-80% by 2050. The fact that issues of pro-ecologically orientated energy and fuels are presently given a global dimension results from several economic, social and, above all, environmental factors, of which the main ones are as follows.

Systematically growing demands for primary energy, which are closely connected with demographic changes and lifestyle. The prognosis given in the report of the International Energy Agency (Energy Information Administration 2009) shows that there will be a gradual change in the relation between energy production from fossil fuels and from renewables. It is anticipated that in the course of the next 20 years the share of renewables will be about 20%. All energy resources will be developed but the dynamics will be different. The scenarios for oil and natural gas usage assume a slow increase by 1.2% annually, and a relatively high rate for coal and renewables by 1.9% and over 2%, respectively (Figure 1).

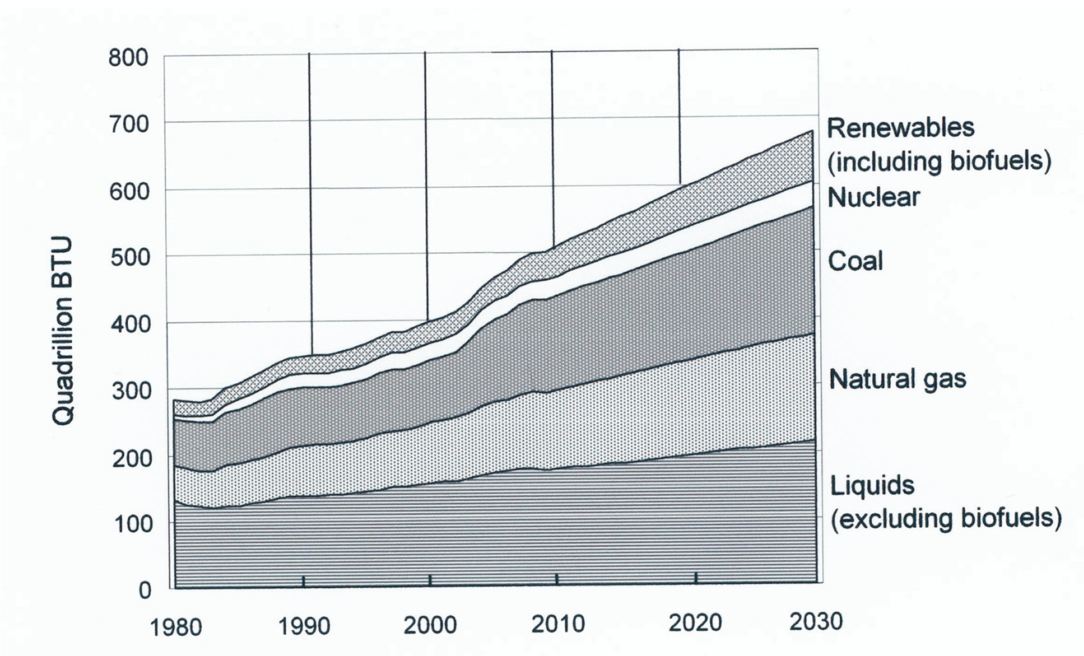

Figure 1. Marketed energy use by fuel type, 1980-2030 (Gołaszewski, according to data of Energy Information Administration/International Energy Outlook 2009; BTU – British Thermal Unit equals 1.055 KJ).

Fossil fuel resources are limited, depletable and the supply and consumption are imbalanced. Strategic fossil resources are mostly at the disposal of politically unstable countries which are commonly with limited democracy. There are many examples from the global fuel market that fuel prices are unstable and dominant exporters do not always guarantee a stable supply. Today we are at a historical point of so called "peak oil", which means that after this peak the exploitation of crude oil may only be lower and the prices higher, so obvious and valid is the sentence that "the era of cheap and easy oil" is finished. At present, in such a phase there are 54 out of 65 countries which are oil suppliers, and since the 1960-ies the number of new oilfields is getting systematically lower – from newly discovered oilfields there is only 1/6 of a global supply. According to the Association for the Study of Peak Oil the peak of crude oil and liquid gas (NLG) production will be in 2010-2015 and in the case of natural gas its supply will steadily increase by 2040 and after that there will be a strong decrease in supply (Figure 2).

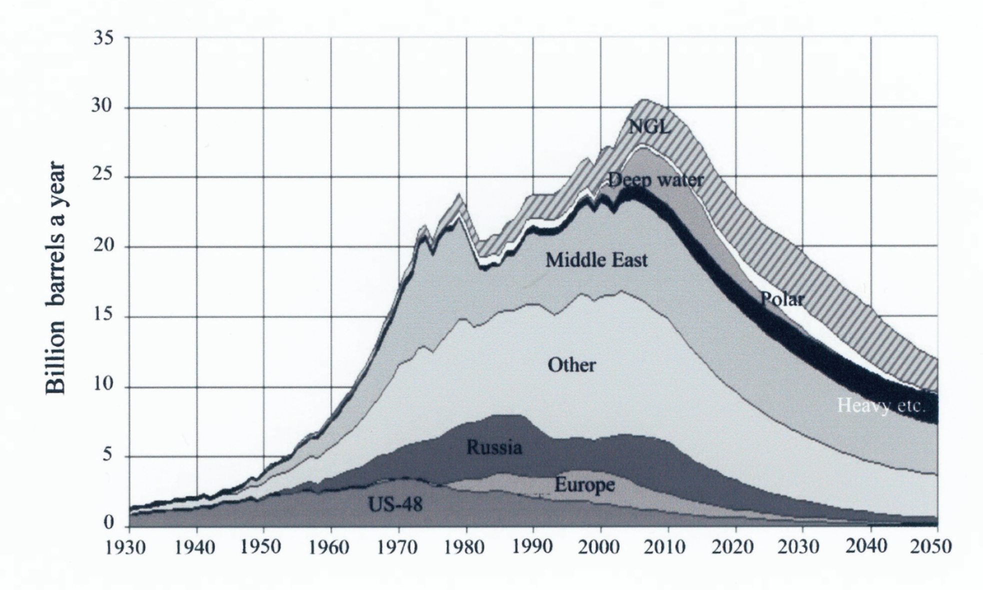

Figure 2. Oil and gas liquids 2004 scenario (from: Association for the Study of Peak Oil).

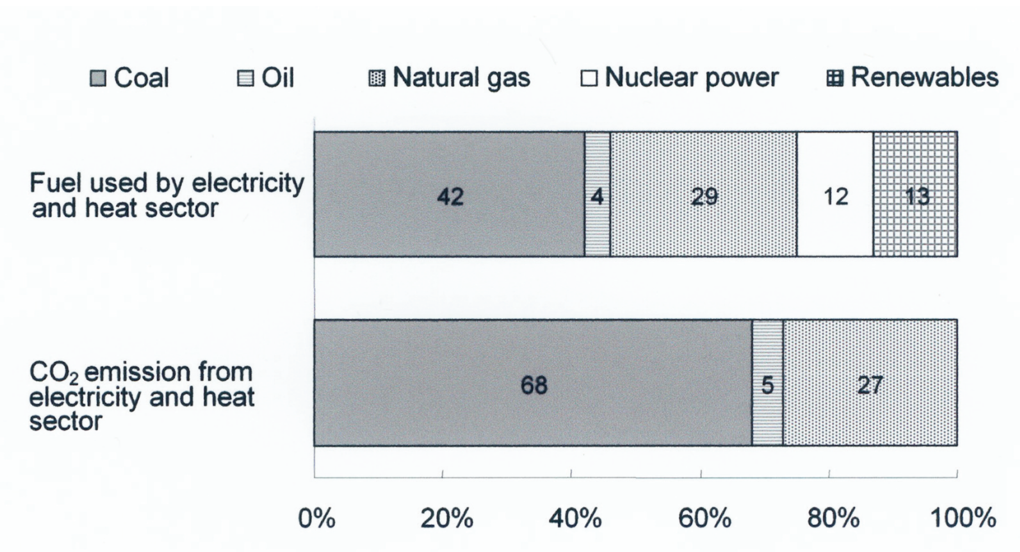

Figure 3. Fuel used and CO_2 emission from electricity and heat sector (Stern Review 2007).

Conventional and dominating today's combustion of fossil fuels for energy production creates the emission of exhaust fumes into the atmosphere and enhances the greenhouse effect. Fossil fuel combustion alone emits 6Gt of CO_2 annually and it doubles the amount that the biosphere is able to absorb. The main emitters in electricity and heat sector is coal and natural gas (Figure 3) (Stern 2007).

It has been estimated that if the present trends of greenhouse gases emission continue, the total human emission of CO_2 will be increased by 45% from the present 28Gt per year to 41Gt per year in 2030 (Figure 4), which may result in an increase of a temperature by 6°C (World Energy Outlook 2008, OECD/IEA 2008). Let us note that at present the level of CO_2 emissions is significantly higher than the acceptable level estimated on 10Gt of CO_2 emissions annually. The following example of some theoretical calculations is very revealing. If we assume that all the inhabitants of the Earth, circa 6 billion, would be able to live according to US standards, the total emission of CO_2 would be at the level of 150Gt (5 times more than it is today). Clearly everyone wants to live comfortably, but comfortable living demands more energy. Today, the economies of many countries are very dynamic, for example China's growing economy emits 20% of global greenhouse gases while in the 1970s China's emission was at the level of 6%. According to Stern's (2006) report, emissions of CO_2 should be stabilized at the level of 450-550ppm (particles per million) and the present emission level of 430ppm (with a trend of its increase by 2ppm annually) the emission should be reduced by at least 80% by 2050.

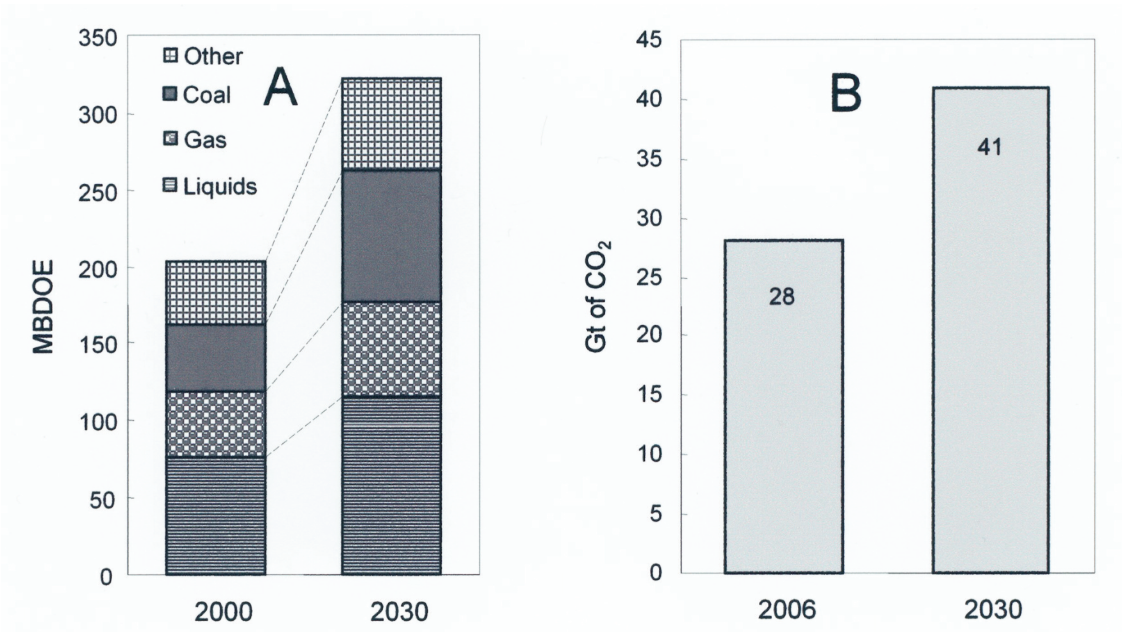

Figure 4. (A) Predicted energy demand and (B) environmental consequence (Gołaszewski, according to World Energy Outlook 2008, OECD/IEA 2008) (MBDOE – million barrels per day of oil equivalent, Gt – gigatons).

Since technologies for energy conversion from renewable sources are known for being less efficient and more expensive compared to fossil fuels, it is necessary to develop new technologies, search for new solutions and continuously introduce innovations. According to the long-term prognosis by 2040 (Uppsala Hydrocarbon Depletion Study 2004) the share of renewables in the energy market will be systematically increased but the present structure of their utilization will be changed (Figure 5). In the next 30 years the share of biomass will be decreased from about 80% at present to about 50% in 2040. At the same time solar energy will be second in the range of renewable energy consumption. It is worth noting that new technologies for use of energy from other energy sources like energy from waves and tides as well as biomass from seas and oceans are also developed, but the present embryonic stage does not allow to make any valid prediction for the future, including also any probable detrimental environmental consequences.

ENERGY (R)EVOLUTION

According to the International Energy Agency (OECD/IEA 2008) the tempo of present changes and development of technologies for energy use from renewables have distinctive

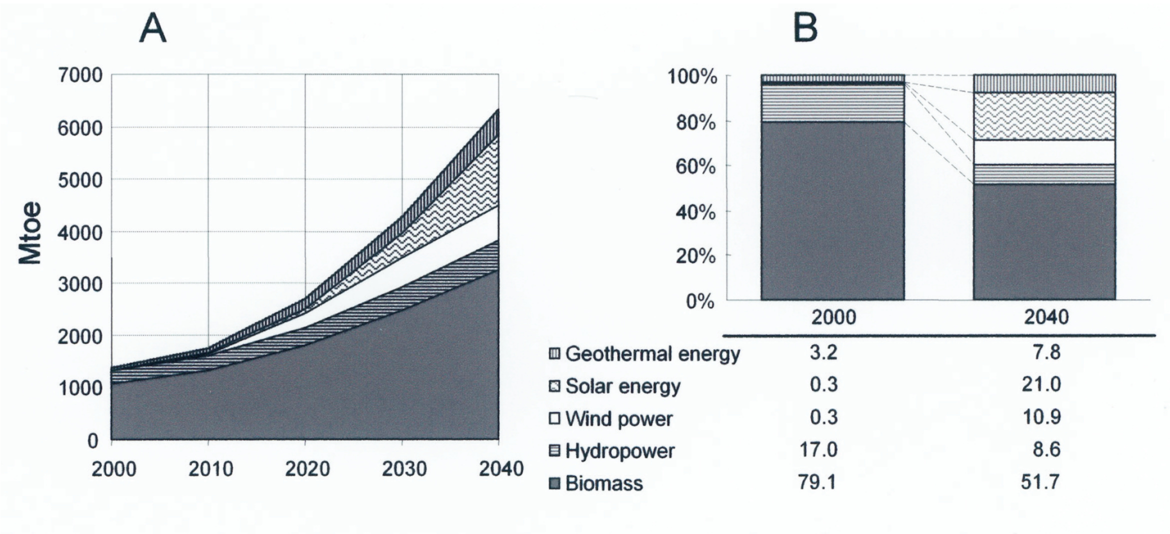

Figure 5. Contribution of chosen RES to the world energy supply in 2004 – report. (A) Mtoes, (B) percentage (Gołaszewski, according to European Renewable Energy Council 2004).

traits of an energy revolution. Some contesters say that it is simply evolution and not revolution. To make it clearer, if the stage may be named revolution or evolution let us look at a classic, like Alvin Toffler (1980) and his book "The Third Wave" and his theories on the development of civilizations. In social development increasing energy needs were always the main stimuli for revolutionary changes and it was always related to taking away of an attribute of man's aptitude for society. In the agrarian civilization (first wave) man was the main source of energy, so when energy was needed the man was hired. In the industrial society (second wave) increased energy was needed for propelling machines and man's energy became redundant and non-essential, but his intelligence was needed for the routine service of machines and mass exploitation of natural resources. The standard of living was getting higher, higher was also longevity, but it was in accordance with higher energy consumption and the intensive devastation of natural environment. Highly significant is the fact that the present generation uses as much energy as all previous civilizations combined. In the postindustrial era encroaching now in the so called information era or civilization of knowledge the next attribute of man's usefulness to society, his routine intelligence was taken away. Any routine activity of man may be done better by computer but man's intelligence and knowledge are still needed for the creativeness to find solutions for the individualized needs of man. High priority has been given to sustainable development, rational exploitation of natural resources and environmental protection together with pro-ecological technologies in every field of man's activity.

Thus, it may be concluded that today the essential prerequisites for the existence of changes in energy sphere have been fulfilled. It brings about the technological boom in the methods of renewable energy use, and what is much more important it is the political will of the main players of the energy market to think globally. „Global Green New Deal" was launched by United Nations in November 2008, and the environmental programs in the European Union with the commonly known slogan "3 times 20 by 2020" (Council of the European Union 2007), and in the USA – environmental program proclaimed by Obama and Biden (2009). In Europe 3·20 means 20% share of renewables in primary energy production, reduction of CO_2 emission by 20%, and 20% energy savings. In the USA the main targets are even more ambitious than in Europe: 25% share of renewable energy, the reduction of CO_2 emission by 1/3 by 2020 and by 80% by 2050, zeroemission federal buildings and 25-30% increase of energy efficiency and conservation.

The next significant element of proenvironmental policy in generating and use of energy is a market mechanism to increase the uptake of renewables by the so called green energy certificates like ROCs – Renewable Obligation Certificates.

ENVIRONMENTAL PARADOXES OF RENEWABLE ENERGIES

Disparity of environmental effects

The notions related to climatic changes and pro-environmental activity by the use of energy from renewables may be diametrically different. Thus, there is a need for a rational motivation for every positive and negative effect of energy production from renewable sources as well as for balancing hurrah optimistic and radically pessimistic opinions. To see the global effects many factors of demographic, economic and social nature and primarily the environmental limitations should be taken into account.

A starting point in such an analysis is to consider a disproportion between developing and industrialized countries. The economic and technological dissonance bring about a specific ecoenergy division of the world for countries with advanced technologies of generation and use of energy from renewable sources on one side and countries with relatively low innovative potential purchasing technologies and creating locally green energy markets (as in Poland) or operating in the global energy market thanks to cheap feedstock, mainly biomass (like in some Asian countries). The countries which invested early in the development of bioenergy and biofuel production are now technologically in the lead. It appears that primacy in this area belongs to Germany, Denmark, Sweden, Austria, Japan, and the USA.

Dynamic and positive changes in the structure of energy use and reduction of GHG in one part of the world (i.e. Europe) does not accompany analogical changes in other parts of the world (i.e. Asia), which means that despite obvious and general advantages the term renewable energy sounds often pejorative. On one hand it stems from an intermediate stage of renewable energy development and difficulties in transposition of the present highly emissive coal technologies in industrialized countries like the USA, as well as in dynamically developing countries like India and China and also countries whose security relies on coal like Poland. The present stage of development of the so called clean coal technologies like CSS "carbon sequestration and storage" does not foster distinctive changes in conventional energy generation from coal. On the other hand growing demand for energy feedstock in developing countries results in environmental devastation by the exploitation of natural ecosystems and limitation of biodiversity, for example by deforestation or exaggerated re-profiling agriculture to energy biomass production.

Above examples point out that in management of global energy resources an equal stages of technological advancement and usage of renewable sources between countries may limit the tempo of changes and deepen the present disproportions and enhance the degradation of valuable natural ecosystems in poorer parts of the world.

Fiction of clean energy

During energy generation burning fossil fuels throws GHG emissions into the atmosphere. On the other hand facilities generating energy from renewable sources, like hydropower plants, wind turbines, solar panels, as well as nuclear plants have zero emission which does not mean that they do not tack on to the greenhouse effect. The reason for gas emissions is the production process and assembly of eco-energy facilities. The same is also with biomass production where effective production requires inputs for production factors like fertilizers, sowing, cultivation and harvest machines but in this case the sequestration of CO_2 from the atmosphere in the process of photosynthesis should be taken into account. So, in the context of final balance of GHG emissions the term "clean energy" is conventional. Among the tools of environmental management are LCA – Life Cycle Assessment, and specifically for ecological estimation of life cycle of gas emissions – LCE (Life Cycle Emission).

The LCA of CO_2 from renewables varies from a marginal to a strong influence (Table 1). Generally, it may be assumed that today the highest emission of CO_2 is related to solar facilities, and the lowest with hydropower plants, which may account for 40% and 2.5% of LCE of CO_2 in comparison to coal burning.

Agriculture is also a significant GHG emitter (Figure 6). Plants sequestrate CO_2 from the atmosphere so in the conditions of the sustainable production of biofuels LCE of CO_2 is relatively low. However, LCE of CO_2 emission is ultimately the result of two factors: 1) energy inputs, cost of fertilizer and cost of biofuel production, and 2) emissions which result from transformation of forests and grasslands to land for energy crop production.

Table 1. Comparison of LCA GHG and CO_2 from non renewable and renewable sources.

Way of energy production	**LCE GHG** (Dones et al. 2003)	**LCE CO_2** (Koch and Frans 2000)	**LCE CO_2** (Varun et al. 2008)
		$g \cdot kWh^{-1}$	
Coal – burning	949–1280	986	975
Natural gas – burning	485–991	450	608
Sun energy – PV	79	–	53–250
Sun energy – thermal	–	372	13–202
Nuclear energy	8–11	31	24
Wind energy	14–21	66	10–124
Water energy	3–27	25	4–237
Biomass		92–156 (wood)	35–158

According to the World Resources Institute (Annual Report 2006-2007) agricultural sector is responsible for 14% of global GHG emission with nitrogen oxides and methane as dominating gases. Among the main sources of emissions in agricultural production are:

- fertilizers, which increase the effect of natural processes of nitrification and denitrification in soils and exoneration of nitric oxides,
- livestock, an important source of methane emission,
- rice production, anaerobic decomposition of organic biomass leads to methane emission,
- storage and fertilisation of livestock waste lead to methane emission,
- burning of biomass (GHG),
- manufacturing of agricultural production factors and activities in broadening the land for energy crops (GHG).

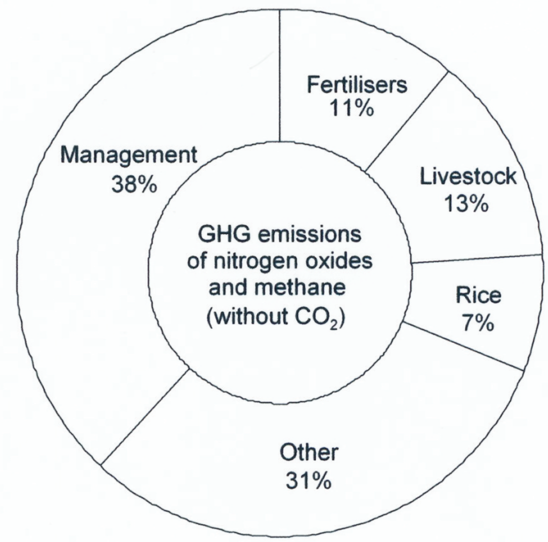

Figure 6. Sources of GHG emission from agriculture (calculated by Gołaszewski according to the US Environmental Protection Agency 2000).

Myth of cheap energy

The question may be asked why the energy revolution did not happen earlier and why the changes are not so distinct as may be expected? Irrelevant of the energy source the cheapest energy is when it comes from cheap feedstock (wasteful exploitation), it is made by cheap labor, with the usage of cheap technology and cheap disposal of waste. An extreme example may be conventional coal power plants which are of low energy efficiency, highly emissive and with hard to calculate long-term interference on man's health (social and environmental costs like diseases, treatment costs, environment contamination). Another example may also be a nuclear power plant having trouble with the disposal of radioactive waste, but also a biogas plant having trouble with waste from fermentation processes, especially when it is contaminated with toxic compounds.

Cheap technology is always preferable to the energy market, i.e. which minimizes production costs related to energy inputs, production process and environment protection. It means that a power plant which does not invest in effective and usually expensive filters as well a biorefinery interested in cheap feedstock without possible perturbation in relation between feed and energy production or in conservation of biodiversity is always competitive. Therefore, does cheap energy have to mean higher environmental consequences? It seems that in a long-term perspective and at the same time in accordance with the assumptions of sustainable development it will be autonomous regulation but today the question if cheap energy equals low environmental consequences is still rhetoric. It may be assumed that in a short-term perspective a particular policy of the owners of fossil fuel resources will be present but their influence will be steadily decreased at the same time with commonality of effective solutions for energy conversion from solar, water, wind or biomass sources which has no owner and no limitations. From it stems the contradiction between energy needs in short and long-term perspectives. What is the opinion of today's conventional energy monopolists on new technologies? They are expensive today – that is true in many cases like bioethanol production from lignocellulosic feedstock or implementing the system of electric cars charged at a network of electric stations. Many opinions are very sceptical and the attitudes are uncourageous and passive which often demonize disadvantageous aspects of renewable energies.

Spurious diversification of agricultural production and enhancement of biodiversity

„Promotion of biofuels goes far towards the reduction of EU dependence on the importation of energy, GHG emissions as well as it will stimulate development of rural areas" – it is a free paraphrase from Directive EU 200/30/EC. It is true that new crops should give broader spectra of a farmer's decision on the kind of production and enhance the biodiversity and as a result, diversification and rural development benefits. However, taking into account the reality of the energy market and obvious competitiveness to petrochemical products it may be assumed that the production of energy biomass will be slowed down. An example of a spurious diversification of crop production is the re-profiling of agricultural production, which in the face of the lack of control mechanisms may lead to the simplification in crop sequence and the restraint of biodiversity.

Myth of increased energy security

In the background of energy crops productivity in the Tropics the inputs on unit of land use under energy crops in Europe are unfavorable (climate, labour cost, land cost, etc.). The potential yield of common crops cultivated in Europe for biofuels like rape for biodiesel and cereals for ethanol are 2-4 times lower than the potential yield of tropical crops like palm oil or sugar cane. For instance, from one hectare of winter rape it is possible to get about 1.2 tons of biooil while from 1 hectare of palm oil 4.1 tons (Figure 7).

High yielding, cheap land and low production costs in the Tropics creates a demand for imported feedstock which in turn causes the dependence on biofuel production of external feedstock and does not contribute to energy security.

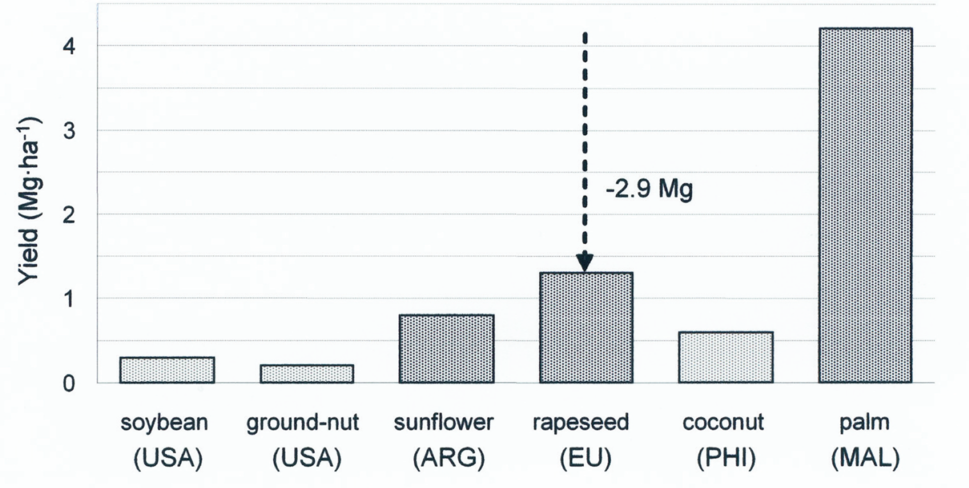

Figure 7. Selected oil crop yields in Mg per hectare (2004-2006 average) (Gołaszewski, according to Lewis 2007).

ENVIRONMENTAL EFFECTS

Biofuels

A t m o s p h e r e . Among biofuels the most important today are bioethanol and biodiesel. In transportation biodiesel may be used directly in diesel engines but bioethanol is usually blended with gasoline. The proportion of bioethanol higher than 10% may require modification of the engine. In general, biofuels are ecologically safe, easier biodegradable than carbohydrates, their combustion emits less fumes, carbon monoxide, hydrocarbons and sulphur, and combustion gas from engines does not contain any heavy metals. Emission of carbon dioxide is 40-85% lower in relation to emissions from crude oil (Table 2). So, it may be said that the combustion of biofuels as opposed to the combustion of fossil fuels contribute very little to the increase of the greenhouse effect.

Table 2. Percentage of CO_2 emissions from fossil and renewable fuels in relation to emissions from crude oil (Gołaszewski et al. 2008).

Fuel	Emissions of CO_2 (percentage of emissions from crude oil)
Gasoline	130
Diesel fuel	115
Autogas (LPG)	135
Methanol	150
Ethanol	30–60
Methanol (from biomass)	20–50
Biodiesel	15–30

It should be noted that the use of biofuels emits as much CO_2 as petrol fuels, but in the case of biofuels the cycle of CO_2 is closed because emitted gas is absorbed by plants from the atmosphere. However, depending on the technology of biofuel production LCA of CO_2 may be different. For instance in organic agriculture where the input of production factors (fertilizers, machinery, plant protection) is at a very low level, the production is very close to be carbon neutral as opposed to the system of intensive production (present corn or rape production).

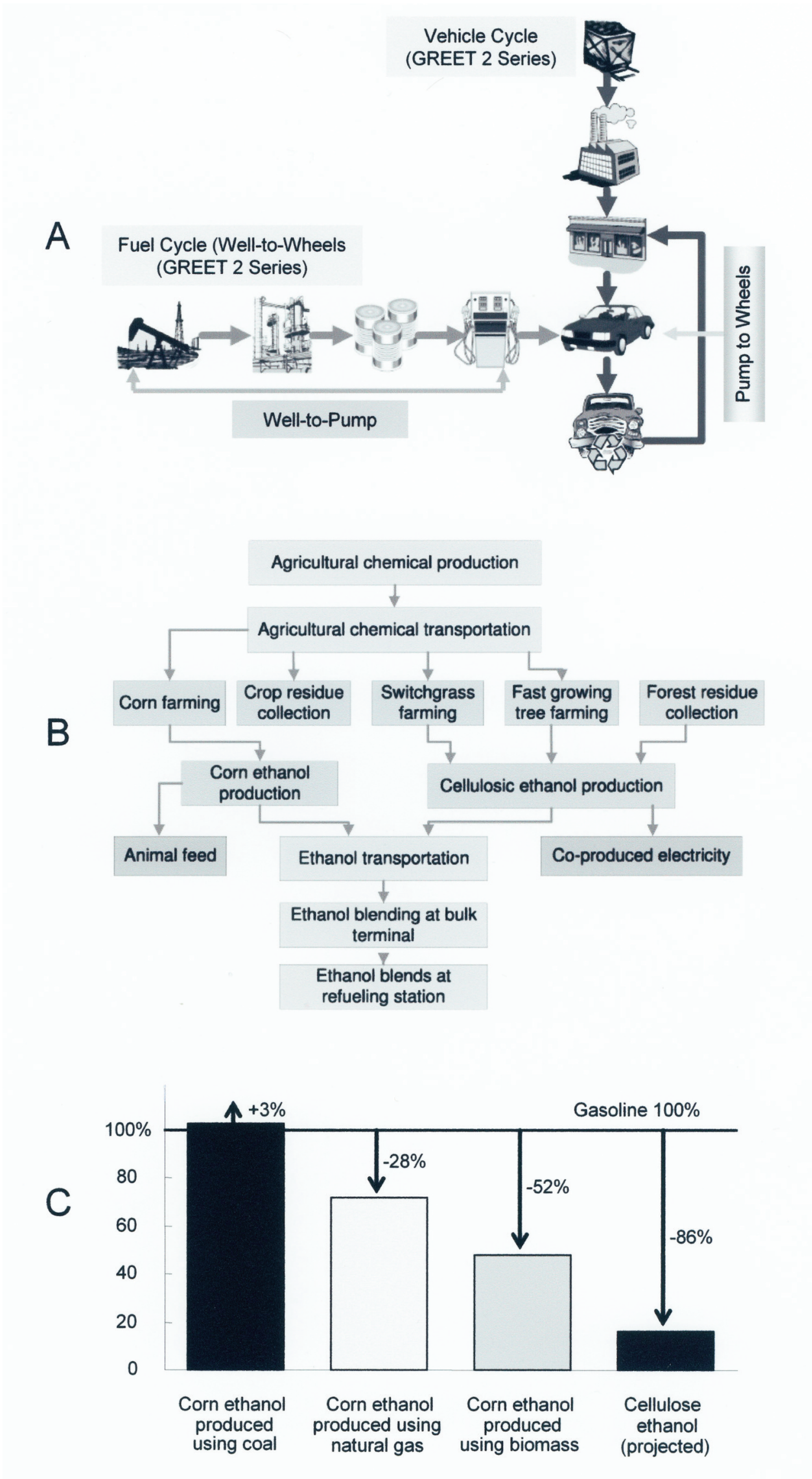

Figure 8. Changes in GHG emissions for the chosen options in relation to the gasoline "well-wheel" life-cycle analysis. (A) LCA of vehicle/fuel systems – GREET model, (B) ethanol production trace in the model, and (C) percentage of changes in GHG emissions (Wang et al. 2007).

Table 3. Biodiesel tailpipe emissions compared to conventional diesel (Morris et al. 2004).

Pollutant	Biodiesel B100
Carbon monoxide (CO)	-42.7%
Hydrocarbons	-56.3%
Particulate matter	-55.3%
Nitric oxides (NOx)	+13.2%
Mutagenicity	-80-90%
Air toxins	-60-90%
Sulphates	-100%

Biodiesel is more environmentally advantageous than bioethanol. On average, reduction of GHG by using biodiesel is about 40% while the use of bioethanol produced from corn is only 12%. Biodiesel in comparison with diesel emits less pollutants, excluding nitric oxides with 13% higher emission (Table 3).

Similarly, in comparison with gasoline, the use of bioethanol emits less carbon oxide, nitric oxides and sulphuric dioxide. As a biocomponet to fuel it reduces solid and liquid particles in the atmosphere and protects the Earth's ozone layer by reducing volatile organic compounds, mainly hydrocarbons.

However, the environmental effects of using biofuels considered in a broad perspective may not be unambiguously positive because of possible damaging changes in ecosystems, imbalance in water economy and reduction of biodiversity (Figure 8).

Farrel et al. (2006) suggest not to treat bioethanol as a source of clean energy. They claim that even if in energy balance the present technologies of bioethanol production require less energy from fossil fuels, the total greenhouse gas emissions are very similar to that of gasoline. According to Wang et al. (2007) among the future technologies of ethanol production from corn considered as "well to wheel" scenario, the most advantageous to the environment may be the use of biomass instead of coal or natural gas. In such a case emissions of GHG may be reduced by up to 52% in relation to gasoline production. At the same time without doubt the most advantageous is variant when ethanol is produced from lignocellulosic feedstock, because the whole process will allow an 86% reduction of GHG emissions.

Water. Evapotranspiration is a natural land potential evaporation and transpiration of plants. Crops utilize water in different way while the distinction between plants with photosynthetic type C3 and C4 (corn, sugar cane) should be done, because plants with C4 type of photosynthesis have generally higher water use efficiency (Table 4). In bioethanol production low indices of water use efficiency have cereals like wheat but also lignocellulosic plants. The highest value on the Table 4, i.e. 95 kg of DM per one hectare and one mm of evapotranspiration, was evaluated for miscanthus (*Miscanthus giganteus*) grown in southern England. On the other paper Berndes (2002) demonstrated that development of energy crops will result in increased evapotranspiration.

Table 4. Evapotranspiration in crops calculated per energy unit of biomass (Berndes and Börjesson 2001).

Energy crops/Biofuels	Water use efficiency $kg_{DM} \cdot ha^{-1} \cdot mm^{-1}{}_{ET}$	Evapotranspiration	
		$Mg \cdot GJ^{-1}{}_{biomas}$	$Mg \cdot GJ^{-1}{}_{gross\ energy}$
Rape	9-12	48-81	100-175
Sugar cane	17-33	23-124	37-155
Sugar beet	9-24	57-151	71-188
Corn	7-21	37-190	73-346
Wheat	6-36	21-199	40-351
Lignocellulosic crops	10-95 (miscanthus)		
Bioethanol		7-68	11-171
Biomethanol		7-68	10-137
Hydrogen		7-68	10-124
Electricity		7-68	13-195

According to the studies of Chiu and Suh (2009) the production of 1 litre of bioethanol from corn in the USA requires on average 263-784 litres of water. In the years 2003-2008 production of bioethanol has been increased by 133% annually (from 13 to 35 billion litres) but in the same time the water use was all out of proportion and accounted for 245% (1.9-6.1 trillion litres). The other unfavourable aspect is the fact that commercial intensive production for energy purposes demands higher inputs for production factors which in reverse may lead to further eutrophication of waters and air pollution. Pimentel (2003) also claims that due to such environmental consequences bioethanol from cereals contributes little to environment conservation.

A biodiesel refinery requires less water per litre of biodiesel than an ethanol refinery. According to Pate et al. (2007) to produce of 1 litre of biodiesel 1 litre of water is consumed.

The one of the commonly used indices of water use, which reflects direct and indirect water consumption, is the water footprint (WF). The index describes the amount of water used in the production of energy unit ($m^3 \cdot GJ^{-1}$). According to Gerbens-Leenes et al. (2008) WF for production of energy unit from biomass is 70-400 times higher than that from other sources of primal energy (excluding hydropower plants). The authors underline that the increased demand for water in accordance with increased biomass production will stimulate dissonance between relations “water and food” and “water and energy”.

To conclude the part of the discussion related to water use it may be stated that maintaining the high production of bioethanol for transportation may in reverse deplete natural reservoirs which is also a fossil source. So, how can we reduce water use when producing biofuels? It should be considered in terms of general hydrologic cycle at a given location but today it may be said that at least two ways are possible – use of new technologies with reduced demand for water (i.e. ethanol from lignocellulose) and recycling of waste water.

B i o d i v e r s i t y. The intense increase of biofuel production may damage biodiversity and among potential reasons of the statement there might be:

- loose protection of native ecosystems, for example in countries like Malaysia or Brazil vast land is taken for production of energy feedstock at the expense of natural ecosystems, also in the USA there are examples that farmers, attracted by incentives for the production of energy feedstock have decided to exclude their land from protection programs,
- reduction in diversification of agricultural production. Good prosperity for biofuels facilitate energy crop production but to preserve biodiversity it is purposeful to launch accompanying mechanisms which will guarantee sustainable development of energy biomass production,
- price disproportion of the same feedstock depending on the demand of the local food and feed market. In this context a distinct example is corn production in the United States. Corn is valuable goods for any markets, it means that energy, food and feed markets depend on it. It causes obvious competition between food and nonfood production but what is also a problem it causes competition on land under other crops, like soybean. For instance in the season 2007/2008 the growing demand of the biofuel market for ethanol caused, secondarily in a sense, replacing land from soybean to corn. It resulted in a deep reduction of soybean production of about 17 million tons, which resulted in a 22% reduction of marginal reserves of this crop in relation to the previous season (Figure 9).
- market pressure. In EU biofuel Directive 2003/17/WE a systematic growth of biofuel consumption up to the level of 10% by 2020 was assumed. In Europe the main biofuel is biodiesel produced from rapeseed oil. In the last seven years the growing demand for vegetable oils has been increased five-fold and the structure of their utilization in food and nonfood sectors has been totally changed (Figure 10). In 2008 it resulted in a shortage of the oils in the European market and the need for import. In the season 2007/2008 the

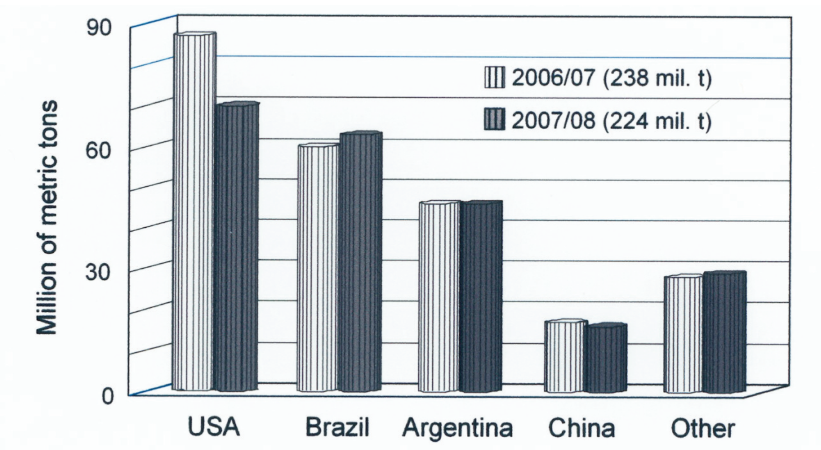

Figure 9. Global production of soybean in seasons 2006/2007 and 2007/2008 (Budzyński et al. 2008).

import to EU accounted for 0.5 million tons, mainly from Asian countries. For example, the growing demand for vegetable oils caused the devastation of natural forest ecosystems in Asia because the forests were designated for the production of palm oil.

In the context of the sustainable development of the biofuel market, Groom et al. (2008) propose some elementary rules in order to protect biodiversity: (i) good agricultural practices, (ii) minimization of land under production of energy feedstock and at the same time to keep a very high efficiency of biofuel production, and (iii) high priority should be given to these biofuels which sequestrate carbon or they have a negative or zero balance of carbon cycle.

From the studies of Fargione and Tilman (2008) stem that replacing forests, moors, savannahs, or grasslands by energy crops in Brazil, South Asian and other countries the so called biofuel "carbon debt" is generated by freeing 17-420 times higher GHG emissions than the reduction of emissions by using biofuels as an alternative to fossil fuels. On the other hand, biofuels from waste biomass (communal wastes, agricultural residuals, residuals from lawns, etc.) or biomass from perennial crops grown on marginal land, devastated or wasteland do not cause the debt and may go far towards GHG emissions.

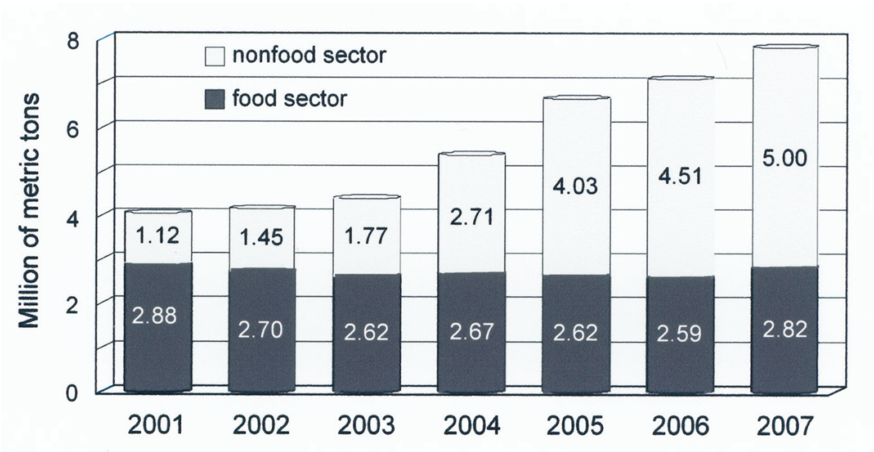

Figure 10. Rapeseed oil consumption in EU-27, 2001-2007.

Wind turbines

In wind energy utilization wind turbines are usually grouped in the so called wind farms. The level of environmental interference is related to the power of turbine but also a very important decision factor is localization of the farm with superior ecological restrictions related to legally protected areas, i.e. according to programs NATURA 2000 or CORINE, and allowable bounds from the areas. It is a common assumption that wind power plants are the classic of clean energy facilities but with such a description it is not taken into account LCA of GHG from the stage of production of turbines and their installation. Varun et al. (2008) estimated that LCE of CO_2 may attain 124g per 1 KWh. For example the installation of wind turbine 2.3 MW with the parameters: hub height 90-110m and the length of a rotor blade 22.5m demands 150 tons of steel, 10 tons of copper, 30 toes of glass fibre and 1000 tons of concrete. When discussing on ecological consequences of wind farms there are also other points taken like an ambiguous aesthetic perception of wind farms in the landscape, practically irreversible changes of soil profiles at the places of foundation, and a perturbation in the structure of biodiversity including an interference on avifauna and living organisms in the vicinity of big turbines. Michałowska-Knap (2006) points out for other shortcomings related to interference of wind farms on human beings including human health, standard of comfort in the vicinity of wind farm, noise, and infrasound. Some of the mentioned above shortcomings are to a great extent discussable. For instance Olech and Juchnowska (2006) on the basis of Dutch research claim that bird mortality related to wind farms is manifold lower than caused by electric grids or transportation, and intensity of noise is marginal and emitted infrasound is out of man's perception.

It is for sure that development of wind energetics will be a significant element of progress in an increase of utilization of energy from renewable sources. However in the future it is essential to rationalize all activities particularly in the sphere of conservation of landscape as well as environmental and cultural values. Among future solutions, apart of big wind turbines, there are proposed turbines of small power mounted in association with other renewable energy facilities and being a part of distributed energy grid.

Water energetics

The installation of hydropower plant as well as the installation of wind turbines demands rational environmental solutions; however, there is a significant difference between the two.

Provided that technological solutions for wind turbines may be considered in terms of a standard in the case of hydropower plants all the installations due to their localization are unique. In dependence on the scale of investment environmental interference may be diametrically different from extremely significant changes in ecotypes, devastation of natural land (and river) ecosystems, and up to displacing people from their abodes to a small hydropower plant with minimal environmental interference and usually in keeping with the landscape. Among negative environmental consequences there are questions of slowing of natural water flow, erosion of riverside or lake shore due to higher water levels, sinking of riverside nests of birds, and monotonous noise of working hydropower plant which may be perceived as inconvenient. In general it may be stated that the small hydropower plant is the source of clean energy and usually plays positive role in the landscape.

Solar installations

Solar and photovoltaic installations converting sun energy into useful thermal and electric energy are perceived as the most pro-environmental ones. It is obvious that they are the most pro-environmental but the final effect depends on the scale. Considering the present level of development and a very energy consuming and expensive technologies of production a serious ecological claim is related to a significant emission of GHG at the stage of production. It causes that at present LCE of CO_2, amounting for 1/3 of CO_2 emissions from fossil fuels, is the highest one among all the renewables. Nevertheless, until the most of solar and PV installations are in the small scale (usually roofs of buildings) the positive environmental effect will be maintained though together with an increased number of solar power plants installed on large areas (deserts but also on land with a potential for crop production) the list of ecological arguments and consequences may be changed.

Geothermics

Geothermal power plants usually use steam and potential disadvantageous environmental effects may stem from the chemical composition of hot water resources. Greenhouse gases emissions are minimal, and among gases nitrogen oxides are not present, there are emissions of CO_2 and SO_2. Today, efficiency of present technologies are not satisfying and they are expensive but surely in the course of permanent development geothermal energy will have broader usage than today.

SUMMARY

The environmental paradoxes related to exploitation of renewable sources were discussed, including a question of disparity between environmental effects, clean energy fiction, the myth of cheap energy, apparent diversification of agricultural production and enhanced biodiversity. In reference to biofuels, wind turbines, hydropower plants as well as solar and geothermal facilities, their interference with environment is analyzed from the point of view of environment management and protection. It has been stated that energy from renewable sources has become a significant component in the structure of supply and consumption of primary energy. This energy is an equivalent of energy from fossil fuels that has a great potential of reducing greenhouse gases emission. At the same time, differences in technological advancement of energy conversion from renewable sources between countries may deepen the present disproportions and cause secondary degradation of valuable natural ecosystems. Thus, rationalization of activities in order to capture specific equilibrium between positive and negative consequences of utilization of energy from renewable sources is purposeful. Rational use of renewables together with providing for environmental requirements will facilitate sustainable energy development.

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