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# ECONOMIC AND ECOLOGICAL ASPECTS OF UTILIZATION OF CONVENTIONAL AND RENEWABLE ENERGY SOURCES IN ECONOMIC PROCESSES

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ABSTRACT. In the article the potential and utilization of conventional and renewable energy are shown. The problem of economic profitability of management is discussed and its influence on natural environment.

**Key words:** conventional energy, renewable energy, energy management

## Introduction

Every country's potential for economic development depends heavily on its energy resources and on the energy-consumption level of production processes occurring in the economy as a whole. At the moment, the major sources of energy include fossil raw materials or conventional energy sources, such as crude oil, natural gas, hard coal, and brown coal. Given the progressing exhaustion of this kind of resources and to their proven negative effect on the natural environment, there has been a growing interest in another group of resources – the so-called renewable energy sources (RES), including solar radiation, wind, water, geothermal springs, and biomass.

So far, the main obstacles to extensive utilization of renewable energy sources have included high cost of processing systems for converting such primary sources into electric power and thermal energy, and low public awareness of the necessity to protect the natural environment. Air, soil, and water pollution caused by the utilization of fossil fuels is so extensive that further radical changes in the energy policy are urgently required. The underlying issue is: how to reconcile business interests of energy distributors, on the one hand, with the best possible protection of the natural environment, on the other hand? This paper attempts to compare the utilization of two different types of primary energy sources in terms of their cost effectiveness and their effect on the natural environment.

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## Potential and utilization of conventional (non-renewable) energy sources in Poland and worldwide

From the early days of the human civilization, people used renewable sources of energy and it was only the construction of the first heat engine and the extensive use of coal in the late 18th and the early 19th centuries that caused rapid development of industry and transportation. This was also the beginning of the massive utilization of crude oil and electric power, which is now extensively used in the world economy. In the contemporary world, obtaining, processing and utilization of energy are fundamental processes in economic activity, since energy – along with water, food, and air – is a major physical need of contemporary humans. Growing energy consumption has enabled economic development and made it possible for the mankind to reach its current civilization level, i.e., the technical civilization. A particularly rapid growth in energy consumption was observed in the years 1945-1970, when the average annual increase was about 5%. In 1973 the world economy was affected by the first energy crisis, with the second one to come at the turn of 1980/81, when the price of crude oil went up 13 times. This resulted in limited industrial production, high inflation, and increased unemployment. The belief about the limited nature of oil resources and other non-renewable fuels became widespread. There were more and more appeals for more rational use of energy and for reducing the power industry's negative effect on the natural environment. Many countries decided that in a long-term perspective crude oil should be replaced by natural gas, atomic energy, and coal. Poland was moderately affected by both energy crises due to its heavy reliance on coal, but the result of the increased oil prices was that revenues from coal export were no longer sufficient to cover the import of other raw energy carriers (**Szymczyk** 2005).

Non-renewable energy sources are those which are not naturally replenished or which are renewed at a much slower rate than they are consumed. These are primary energy carriers including fossil fuels (coal, crude oil, natural gas) and nuclear fuels (uranium, deuterium, lithium). Through processing they are converted into secondary energy carriers, i.e., electric power and heat, which are used directly in business and household processes.

According to the World Energy Council, for the past 30 years primary energy consumption has grown more than 2.5 times. In 1998 global energy consumption reached 410 EJ. Fossil fuels generated 78% of the total energy volume, in the following proportion: crude oil – 142 EJ, natural gas – 85 EJ, coal – 113 EJ. Nuclear energy provided 26 EJ and renewable sources – 44 EJ (**Żurawski** 2003).

Estimations of energy resources change and their identification is still incomplete. Many regions have not been geologically explored, while others have been explored inaccurately. Some countries conceal their actual level of resources for strategic reasons. It is speculated that increasing the concentration of exploratory drillings and, especially, deepening the drillings and making a more extensive use of geophysical methods, will lead to a discovery of new deposits of raw energy carriers. Out of the already identified reserves of fossil fuels, coal makes 81% of the total volume, crude oil – 16%, and natural gas – only 3%. According to the most recent estimations, if today's consumption rates are maintained, the exploitable reserves of fossil fuels should be sufficient for: crude oil – 44 years, natural gas – 57 years, hard coal – 200 years, and brown coal – 300 years. It is estimated that the so-called potential reserves of the above mentioned fossil fuels are more than five times larger than their identified reserves. A different picture emerges when we consider the volumes of resources that may be obtained cost-effectively with the current levels of prices and technology. Another important factor involves uneven distribution of each of these fossil fuels around the world, which generates political and economic dependencies and is a permanent, potential source of crises. The situation is aggravated by multinational corporations that impose their conditions concerning the volume of exploitation, trade, and fuel prices on consumers. As an illustration, the OPEC member states own 77.2% of the global oil reserves and 41.4% of natural gas resources; the United States have 22.1% of the global coal reserves; and 38% of the world's natural gas reserves are located in the former USSR territory (**Ruszkowski** 1999).

**Hard coal** is a crucial fossil fuel used primarily to produce electric power and heat. A proportion of coal is also utilized in the cement industry and consumed by households. More than two thirds of the globally consumed coal is utilized by three countries: China, the United States, and India. Large volumes of coal are also used by Australia, South Africa, Russia, and Poland. It is estimated that the above mentioned countries consume 81-82% of the globally utilized coal. Among European countries, Germany is the largest coal consumer, followed by Poland, the UK, the Czech Republic, Turkey, and Spain. However, European coal consumption has been gradually decreasing. Recent data show downward trends in coal consumption across Europe (**Olkuski** 2005 b). Throughout 1990s coal consumption in the European Union fell by 26.14%. In the same period Poland observed a 29% decline in the utilization of coal, that is by 3% more than in the EU. In 2000 the overall coal consumption in Poland, which amounted to 85 M. t, was distributed as follows: 54 M. t was used for electric and thermal energy production, 7.5 M. t – by households, and 1.5 M. t by agriculture. The remaining energy volume was used by the construction industry, transportation and other industries.

Another fossil fuel is **brown coal**, which is utilized nearly exclusively for production of electric power. In 1998 and 1999 the largest proportion of this raw material was consumed by Germany, which utilized 153.6 and 149.7 M. t, respectively. The United States were the second biggest brown coal consumer (72.8 and 75.7 M. t, respectively), while three other countries – Australia, Greece, and Poland – utilized comparable amounts of brown coal, i.e. 60.4-66.3 M. t. Small volumes of this raw material are consumed in France (about 1 M. t), where nuclear energy is the major source of electric power (**Olkuski** 2005 b).

**Crude oil** is a highly desired raw carrier of energy around the world, but significant deposits of this material – sufficient to make economies energetically independent – are located only in the Middle East (Saudi Arabia, Kuwait, United Arab Emirates, Iran, and Iraq), in the Caspian See basin, and – to a lesser extent – in Third World countries. In Poland there are economically insignificant oil deposits in the Krosno-Jasło Basin (south-eastern Poland) and deposits of some economic significance near Bochnia, Kazimierza Wielka, Dąbrowa Tarnowska, Mielec, in the Baltic littoral, and in Ziemia Lubuska (western Poland). Although in the past years the share of crude oil in the global consumption of primary energy has been slowly decreasing, it is still estimated at the level of 35-40%. Further, gradual fall is expected in the years to come, however the decline rate will depend on the level of consumption of other energy carriers, primarily natural gas and renewable energy. There are inter-country differences in the share of oil in the overall energy balance. Generally, in highly industrialized countries it is between

35 and 40% – e.g., 39% in the US, 41% in Germany, and 35% in Canada. Very high shares are characteristic for Japan (48%) and Italy (52%).

The United States consume more oil than the entire European Union (before May 1, 2004), which utilized 634.4 M. t annually. There are great imbalances in oil consumption across the world. The world's ten largest consumers utilize as much as 60% of the globally consumed oil.

Today only tiny amounts of crude oil are used in their natural state. Virtually the entire output goes to refineries and petrochemical plants, where the distillation process is used to convert crude oil into products such as gasoline, kerosene, diesel fuel, and industrial oils (manufactured from residuals). Crude oil plays an important role in many modern industries. In the world economy the largest quantity of oil is utilized in transportation, especially car transportation (41%). Air transport consumes 7% of oil, sea transport – 3%, and rail transport – 1%. The remaining oil is utilized by the power industry (37%) and by the petrochemical industry (7%).

In Poland the share of oil utilization in the overall primary energy consumption is 20%, i.e. about twice lower than in highly industrialized countries. In 2001 Poland used 19 M. t of oil – 5% less than in 2000 (20 M. t). More than 80% of Poland's demand for oil products is satisfied by domestic production. Crude oil is processed by seven refineries located in Płock, Gdańsk and in southern Poland: in Czechowice, Trzebinia, Gorlice, Jedlicz, and Jasło (**Szurlej** 2005 c).

**Natural gas** is a major source of energy in many countries. It is ecologically purer than coal or crude oil. Other advantages of this primary energy carrier include high heating value and high efficiency of the combustion process, combustion without smoke, soot or ash, and very low content of environment pollutants in fumes (there is virtually no sulfur dioxide and dust).

The world's gas reserves are enormous and its prices are closely linked to oil prices. Since 1999 Poland has extracted 4.3 M. t of natural gas, which is insufficient to satisfy the needs of the Polish economy. Consequently, it is necessary to import this energy carrier. Large supplies of gas coming from various directions may have a stabilizing effect on artificial jumps in oil prices. Poland is located at a crossing of gas "routes" from Siberia, from the North Sea deposits through Denmark, and from North Africa, via Italy and Yugoslavia. Moreover, large LNG ships from South Africa and the Middle East may dock at Polish seaports. Competition among so many exporters may lead to a reduction of gas prices and to eliminating Poland's strategic dependence on oil and gas supplies from just one direction – i.e., from Russia (**Dakowski** and **Więckowski** 2005).

In 2001 the share of natural gas in the global consumption of primary energy was 23.72%, with further growth predicted. In the EU this share remains at the same mean level as in the rest of the world – 23.8%, with significant differences occurring among the 15 "old" member states. Natural gas is dominant in The Netherlands (45%), the UK (40%) and Italy (33%), while in Portugal and Greece its share in the overall energy consumption is very low (10% and 6%, respectively). The world's largest natural gas consumers are the United States and Russia. High levels of gas consumption are also observed in the UK (a growth tendency in the past years), Germany (stabilized consumption), Canada and Japan (growth tendencies), Ukraine (decline since 1996) and Iran (considerable growth) (**Szurlej** 2005 b).

Major **nuclear fuels** include uranium, thorium, deuterium and lithium. They are an important supplement to fossil fuels around the world. The nuclear power industry developed rapidly in 1960s, to slow down in 1970s and nearly stop in the late 1980s in many Western economies. The key causes behind the stoppage included potential ecological threats and a decline in the economic competitiveness of nuclear energy. Elaborate requirements and safety regulations led to a twofold extension of the average time of nuclear unit construction – from four years in the late 1950s to eight years in 1970s. This, in turn, cut the return on investment rate by 35-40%. However, the main cause of nuclear energy's retreat from the world economy was the growing public resistance against the atomic power industry, which escalated after the Chernobyl disaster. In several European countries (Italy, Switzerland, Germany, Spain, and Sweden) and in the United States the development of the nuclear power industry was virtually halted. Only a few highly developed Western countries (France, the UK, and Canada) resisted the tendency.

Despite numerous problems, today the nuclear power industry continues to develop, although not as fast as it was predicted in 1960s. Between the early 1970s and 1995 the volume of energy generated by nuclear power plants grew nearly 30 times and these plants' share in the overall energy production reached 18%. In the late 1990s the US had the largest number of nuclear reactors (109), followed by France (56). New nuclear power plants are built mainly in Eastern and Southern Asia (Japan, South Korea, China, and India), where fast economic development leads to a rapid growth in the demand for electric power.

According to the principles of the Polish energy policy until 2020 (adopted in 1996), there are no plans to start up a nuclear power plant before 2010. This approach results from high cost of launching nuclear energy production and from negative public attitudes related to threats posed by such energy carriers (**Ruszkowski** 1999). Consequently, longer-term development of the nuclear power industry in Poland will be contingent on the following factors: public approval, economic competitiveness, and legal regulations.

## Potential and utilization of renewable energy sources (RES) in Poland and worldwide

The 1973 energetic crisis, the gradual exhaustion of fossil fuel reserves (related to the growth of the human population and to the steadily increasing energy consumption), and environmental concerns considerably enhanced the world's interest in renewable energy sources in 1990s.

In December 1997 the European Commission developed and adopted the "White book: energy for the future", which showed that the utilization of renewable energy sources in the European Union was uneven and insufficient. Three strategic goals of the EU energy policy were defined: enhancing general intracountry competitiveness, ensuring sufficient supplies of energy, and protecting the natural environment. At the same time, the European Commission set the objective of increasing the share of renewable energy sources to 12% in gross energy volume and to 22.1% in electric power consumption. These targets mean that fuel prices should fall by EUR 3 billion annually, carbon dioxide emission should diminish by 400 M. t, and fuel import should go down by 17.4%.

After four years' work, in 2001, the EU countries adopted a directive (2001/77/EC) which became the binding regulation concerning renewable energy sources. The purpose of the directive is to promote increased RES share in the electric power output on the internal market, and to form the basis for the EU's future framework program. Moreover, a gradual growth in the demand for electric power from renewable sources is expected. The directive provides an evaluation system to monitor its effectiveness. The year following the adoption of the directive and every five years member states are required to develop a report presenting the domestic share of electric power from renewable sources in the overall balance, together with a description of the undertaken and planned activities (**Żurawski** 2003).

Today, most of Europe's "green" energy comes from hydroelectric power plants and biomass. Given the limited developmental potential of the hydroelectric power industry in the EU, much emphasis is placed on the use of other renewable resources, especially solar radiation, wind, geothermal energy and unconventional types of biomass. The European Commission has proposed several specific directions of the EU's fuel and energy management, such as increasing the use of ethanol and vegetable oil obtained from biomass to the level of 5.75% by 2010, improving the efficiency of energy-related processes, a more extensive use of combined electric power and heat production, and the so-called emissions trading (**Ameryka...** 2002).

The Polish legislation includes regulations concerning natural resources management and the objective of increasing the utilization of energy from renewable sources. The environmental act (**Ustawa...** 2001) provides that natural resources should be managed in accordance with the principles of balanced growth. These include limiting their exploitation to the necessary minimum, seeking substitutes, and giving priorities to those construction and technological undertakings that ensure more economical use of natural resources. Rational utilization of energy from renewable sources was defined as a major element of balanced growth, which is an overriding principle included in the Polish Constitution and in the "Strategy for Poland's balanced development till 2025" (**Strategia zrównoważonego...** 2000).

The act on energetic law (**Ustawa...** 1997) includes a provision granting the Minister of Economy the right to impose the obligation to purchase non-conventional and renewable energy as well as electric power generated in combination with heat production on companies trading in electric power and on energy distributors. The act defines renewable energy sources and those using the energy of wind, solar radiation, geothermal resources, waves, sea currents and tides, and river falls, as well as energy obtained from biomass, dump biogas, and biogas generated in the processes of sewage treatment or by stored plant and animal remains.

Based on the Parliamentary Resolution of July 8, 1999, the Polish Ministry of Environment has formulated the strategy for renewable energy development (**Strategia rozwoju...** 2000) which promotes the development of renewable energy sources and the creation of favourable conditions for such development. The strategy assumes that the share of RES energy in the overall energy balance will reach 7.5% by 2010, and 14% by 2020 (**Kompała-Bąba** and **Błońska** 2005).

The technical potential of renewable energy sources in Poland is similar to their potential in other EU countries, and is estimated at 30-60% of the overall demand for primary energy. The fundamental difference between Poland and a majority of EU countries involves the level of RES utilization. By the late 1990s EU countries used 16% of their renewable energy resources (on average), whereas in Poland RES utilization is estimated at 4-9% and is associated primarily with wood and timber waste processing for energetic purposes. According to experts' estimations, by 2070 the share of RES will have reached about 70% of the overall energy consumption (**Wiśniewski** 2000).

Rational utilization of energy from renewable sources is associated with notable ecological and energy-related benefits, including (**Strategia rozwoju...** 2000):

– improved condition of the natural environment (lower air pollution, mainly due to such resources' minimal share in the emission of greenhouse gases; reduced waste production and lower pollution of water),

– more effective utilization and conservation of raw energy carriers,

– enhanced energy security at the local and national levels; more independence from foreign resources,

– more employment opportunities (potential for more workplaces) related to the fact that renewable energy sources are highly dispersed, based on diverse, local resources,

– promotion of regional development;

– improved power supply for regions with poorer energy infrastructure,

– potential for utilizing highly polluted soils, not suitable for growing edible plants.

The major inconveniencies of the utilization of renewable resources are related to high prices of non-conventional energy. "Green" energy is nearly twice as expensive as energy obtained from conventional sources. Another limitation related to the utilization of RES involves technological risk, which is associated primarily with the uneven production cycle. As a consequence, it is necessary to supply energy systems that take "green" energy with a reserve conventional source of energy. Objections are also raised about ecological aspects of renewable energy. To support them, critics provide data about high mortality rates among birds whose migration routes often cross wind farms. Also, some researchers express doubts about obtaining energy from biomass, which – they say – can hardly be referred to as "ecological", as it assumes processes such as burning up valuable wood. This has affected the timber industry which now has to compete for material with biomass energy producers (**Chmal** 2005).

**Solar radiation energy –** the largest, virtually inexhaustible energy source available to humans – is another important and promising non-conventional source of energy. The volume of this energy is 10 000 times bigger than the current global consumption of fossil fuel energy. The ubiquity of solar radiation solves the problem of transporting energy, as it may be obtained anywhere, with no need to build costly transmission systems. There remains, however, a problem of effective utilization of this resource, related to low density of energy obtained from solar radiation. The highest average density of solar energy falling on the Earth's surface is observed in the tropical zone. However, the region characterized by the greatest annual amount of solar energy absorbed by square meter is not the equatorial zone, but – as a result of more hours of sun exposure per day – the temperate zone. Furthermore, the amount of energy reaching the earth surface depends on factors such as the time of the day, the level of dust in the atmosphere, and optical characteristics of the earth surface (depending on the type of cultivation, afforestation, and other features), and the altitude above sea level (**Cieśliński** and **Mikielewicz** 1996).

The amount of solar energy reaching the earth surface in Poland is comparable to that observed in other European countries, where the levels of solar energy utilization are much higher. Countries such as Germany, Denmark, and The Netherlands are advanced users of solar energy. Geographically, the most favourable conditions for utilizing solar energy in Poland are observed on the Baltic coast and in eastern Poland. In Poland the share of solar energy in the national energy balance is virtually ignorable. This results from factors such as weather conditions characteristic for the country and, primarily, uneven distribution of radiation throughout the year. About 80% of the overall annual solar exposure occurs during the six months of the spring and summer season. However, the main obstacle to widespread use of solar systems in Poland is the high cost of equipment converting solar radiation into other forms of energy, which is related to high levels of material and energy consumption characteristic for the processes involved in the production of such equipment. These appliances usually require large collectors, so solar energy turns out to be most cost-effective when used to satisfy small, local needs. It should be emphasized that the process of obtaining solar energy itself is not associated with large operating costs.

The greatest advantage of solar energy processing is its minimum effect on the natural environment (apart from the production of equipment). The production of electric or thermal energy from solar radiation does not cause any pollution, noise, or landscape deformations (**Skoczek** 2005).

**Wind** (or "blue coal") is another renewable resource, characterized by great kinetic energy, easily convertible into other energy forms. On the global scale, the occurrence of winds is incidental and uncontrollable – this applies both to their directions, and to windspeed. This energy source is also highly unstable and its occurrence depends on the geographic region, season, time of the day, landform features, and the altitude above sea level. Wind blowing with a speed of 4 to 30 m/s is considered suitable for the use of turbine generators of electric power. In Poland the average annual windspeed fluctuates between 2.8 and 3.5 m/s. Mean speed over 4 m/s, which is regarded as a prerequisite for effective conversion of wind energy, occurs at altitudes of at least 25 m, in two thirds of Poland's overall area. It is estimated that one third of Poland has adequate conditions for the development of wind energy, especially lower power energy. Regions with most favourable wind conditions include northern Poland and the north-eastern part of the Suwałki region. In Europe, Germany is the leader in the volume of power generated by wind turbines (with more than 16 thou. wind turbines in 2005), followed by Spain, Denmark, and The Netherlands. Poland has several dozen of such devices (**Dakowski** and **Więckowski** 2005).

Contemporary research on the use of wind power focuses on inshore waters and the open sea, where winds show more stability and blow with higher speeds. One problem associated with utilizing wind power for energy production involves energy storage. At the moment, batteries are used for this purpose, but this solution is far from perfect due to batteries' limited capacity and to energy losses. Another way may involve the utilization of surplus electric power for water electrolysis, resulting in hydrogen production. Hydrogen, in turn, may be used as a driving force for the turbine on windless days.

The electric power generated by wind power plants is ecologically pure, because its production is not associated with emissions of any contaminating substances, does not pollute soil, underground waters or surface waters, and does not generate harmful electromagnetic radiation. Wind power plants are serviceless systems, which means that when connected to the power network, they are steered automatically and operate without any human participation. All they require is periodical supervision and maintenance. Their operating cost is relatively low and potential losses in power transmission are insignificant, too.

Basic disadvantages related to wind energy include: temporal power variability, noise, threat to birds, changes in landscape, disrupted TV reception, and relatively high capital investment (**Ruszkowski** 1999). Prior to making a decision on the location of a new wind power plant, the area should be assessed in terms of noise emission, potential environmental effects, and the routes of seasonal birds' migrations. Wind farms should be located in carefully selected sites, at least 500 m away from the nearest human settlements (**Mirowski** 2005).

Out of all renewable energy sources, **water energy** has the largest share in the overall energy output. Water energy constitutes about 2% of the global consumption of primary energy. This includes energy obtained from inland flows, sea/ocean waves, currents and tides, as well as sea/ocean thermal energy (**Ruszkowski** 1999).

The use of sea tides requires special natural conditions – landform features, bays or funnel-like river mouths facilitating the construction of dams, and tide heights over 5 m. There are about 30 places in the world with favourable conditions, where tide heights exceed 10 m (e.g., the Bay of Fundy in North America, the French coast near the English Channel, and the White Sea shore).

Wave energy is a fraction of wind energy. There are considerable technical difficulties with its utilization, related to factors such as the necessity to allow for extreme stresses that may occur under stormy conditions, as well as frequent weather changes and the resulting variability of wave height and other characteristics. Today, wave energy is used primarily to power several hundred navigation buoys on Russian, American, Canadian, and Japanese coasts.

For a number of reasons (both technical and economic) only a proportion of sea currents is suitable for energy production. An ocean power plant is two to three times more expensive than a conventional power station, which makes the former uncompetitive, despite clear ecological advantages of energy obtained from sea currents (e.g., the north-western Atlantic Ocean or the Japanese coast).

Sea/ocean thermal energy is generated as a result of differences in sea water temperature. It is usable primarily in the equatorial zone, where the temperature of water reaches 30°C near the surface and falls down to about 7°C at the depth of 300-500 m. Such power systems' efficiency is very low – only 2-3% – but the source is inexhaustible and always ready for utilization. Such power plants operate in Indonesia (on the Bali island), in Japan, in Tahiti, and in Hawaii.

In Poland water energy is obtained primarily from river falls. The power of big rivers provides 7% of the overall energy output. More hopes, however, are pinned on small hydroelectric plants (SHEP), which not only pose no threat to ecosystems, but can even have positive effects on water management and the natural environment. The use of SHEP brings about a number of accompanying effects, such as water retention, reduced erosion, landscape formation, creating new habitats for valuable plant and animal species, and the development of recreation. Hydroelectric plants are unevenly distributed around Poland. The highest concentration of such systems is observed in the basins of large rivers – Vistula and Odra – and in Pomorze (near the Baltic cost). At the moment there are about 400 small hydroelectric plants in Poland, mainly in northern provinces and in south-eastern Poland (Podkarpacie) (**Dakowski** and **Więckowski** 2005). According to the principles of Poland's Ecological Policy until 2025, there are plans to increase SHEPs' overall power, partly through modernization and expansion of the existing systems (allowing for the agricultural plans related to the restoration of fish populations).

Even though hydroelectric plants are incomparably less harmful for the environment than conventional power plants, they are not entirely harmless. They may lead to changes in the microclimate and the local flora. They may also cause flood threats, contribute to disruptions in the local hydrologic balance, and disturb water routes. Construction of hydroelectric plants may also be associated with relocations of local residents and with increased seismographic activity (**Konwencjonalne...** 2005).

Another renewable source is **geothermal energy**, i.e., the natural heat produced inside the earth and accumulated in rocks, water and steam filling rock pores and crevices. It is estimated that the amount of energy accumulated in the five-kilometer-thick external layer of the earth's crust is many times greater than the energetic potential of all the existing fossil fuels. The warmth of the earth's interior, however, is highly dispersed, which hinders its utilization. Regions rich in geothermal energy include the American Cordillera, Kamchatka, the Kurile Islands, Japan, the Azores, Island, Kenya, and Ethiopia. People are most likely to utilize geothermal water located several meters under the earth's surface, with extraction being economically effective down to 3 km under the ground. In Poland such resources are available on two thirds of the country's overall area, and geothermal water has a potential of providing heat for 30 M. people. These resources constitute as much as 99% of all renewable energy sources in Poland. 80% of the country's area comprises geostructural basins with numerous bodies of geothermal water, the biggest ones being the Szczecin-Łódź basin and the Grudziądz-Warsaw basin. There are four large geothermal heating plants in Poland: Podhale, Pyrzyce, Mszczonów, and Uniejów (**Mokrzycki** 2005).

At the current stage of technological advancement, the primary method of obtaining geothermal energy involves collecting heat from rocks or from geothermal waters via the circulating medium (water). The term "geothermal waters" refers to underground waters available through drilled bores or flowing from natural springs with water temperature above 20°C. Geothermal energy is most likely to be used for central heating, air conditioning, greenhouse horticulture, and animal farming, as well as in the food industry, for drying agricultural and industrial products (such as hay, seaweed, vegetables, laundry, and wool), in recreation, and in balneology. Geothermal energy has a significant share in the overall energy output in countries such as Salvador (about 20% of the overall output) and Philippines (about 18%). In terms of the power of the installed systems that utilize geothermal energy directly, the world's largest users of hot geothermal water include Japan, Hungary, the Commonwealth of Independent States and China. Other major users are the US, France, Italy, Romania, and Turkey.

Comparing to many other energy carriers, especially conventional ones, geothermal energy has many essential advantages. In many world regions its availability is independent on political factors or problems related to international trade in raw energy carriers. Most importantly, it is renewable, independent on climate conditions (unlike hydroelectric plants), and the price of an energy unit obtained from a geothermal plant is stable and lower than prices of traditionally produced thermal energy. The major components of the overall cost of obtaining geothermal energy include the cost of exploratory drillings and the cost of constructing pipelines for transporting geothermal and technological waters. Cost reduction would be possible within a consistent, integrated management system, in which geothermal waters would be obtained from existing bores drilled for other purposes. Geothermal energy may be perceived as environment-friendly, as in most cases it does not cause any environmental degradation. However, there are ecological problems related to the utilization of geothermal resources. One of them occurs when it is necessary to discharge the utilized water to the surface river network, if it is not carried back to the deposit. Increased mineralization (especially salinity) of surface water has a harmful effect on other components of the ecosystem and on physical objects (corrosion). Also, the utilization of geothermal energy is associated with some emission of gas pollutants to the atmosphere, which, however, tends to occur when water temperature exceeds 100°C. In general, the amounts of emitted gases are negligible in comparison to air pollution caused by power plants using mineral fossil fuels (**Ruszkowski** 1999).

In the Polish reality, the form of energy which is the easiest to obtain and the most cost-effective is **biomass energy**, i.e. energy from organic substances of plant or animal origin. Biomass is produced in the process of photosynthesis – it is an accumulated portion of solar energy collected and processed by plant leaves. It may be found in the forms of straw, wood, peat-like sewage sludge or municipal waste containing waste paper. Biomass is most likely to accumulate in the course of production and processing of plant products (e.g., straw in cereal production; or wood waste in the timber, cellulose, and paper industries). It may be also found in the form of plant material grown specifically for energetic purposes (e.g., birch and willow plantations). Sources of animal-origin biomass energy include biogas produced in fermentation processes of manure, sewage sludge, and organic waste at garbage dumps (dump gas). Thus, the main sources of biomass include agriculture, forestry, municipal management, and industry.

Apart from combustion, another ways of obtaining energy from plant-origin biomass include alcoholic fermentation of sugar cane and potatoes to produce ethanol added to engine fuels, and anaerobic methanic fermentation of organic mass. Out of the available forms of biomass, agricultural biomass plays a significant role in energy production, having the potential to become an important substitute for fossil energy carriers. Solid fuel may be obtained from virtually any plant species characterized by high content of dry mass and good combustion features. These plants need less fertilizing and their harvesting does not require any special machines or equipment, so they are relatively inexpensive to grow. Some problems related to agricultural overproduction may be solved through expanding the production of non-food goods and through seeking further industrial applications for agricultural raw materials. One such material is oilseed rape which may be used for production of quality diesel fuel (biodiesel). Such solutions may contribute to agriculture's partial independence from fuels and energy of industrial origin, to reduced environmental pollution, and to increased demand for some agricultural products (**Ruszkowski** 1999).

Every year Polish agriculture and forestry produce biomass equivalent to 150 M. t of coal. Recently, more and more people have been using wood to heat their houses, especially in highly forested rural areas. Due to Poland's relatively low level of afforestation, further potential for obtaining energy in this way is quite limited, although it may be significantly raised through the development of biomass plantations. The most promising source of renewable biomass energy in Poland may be straw, today perceived as useless by most Polish farmers, who tend to burn it in the fields after the harvest season. In terms of heating value, straw is comparable to dry wood, i.e., 1.5 t of dry straw is equivalent to 1 ton of coal. The price of thermal energy obtained from straw combustion is definitely lower than the price of conventional thermal energy, and it is estimated that if boilers are manufactured on a mass scale, the payback period should not exceed four to five months.

For many years numerous countries have successfully utilized biomass as a source of energy. The most advantageous effects are achieved with local solutions. The utilization of this kind of fuel is supported by its harmlessness for the natural environment, as straw combustion is associated with a “zero” emission of carbon dioxide – i.e., the amount of $CO_2$ emitted to the atmosphere in the combustion process is equal to the amount previously taken up by the plants in the process of photosynthesis. It should be noted, however, that straw combustion produces more dust than coal combustion (dust may be eliminated through installing highly effective dedusting equipment). The utilization of biomass contributes to improving the country’s energy balance and to reducing unnecessary wastage of raw materials. Moreover, the launch of biomass plantations creates a new labor market and facilitates industrial development in the areas of production means and biomass processing. One important disadvantage of biomass utilization involves high cost of boiler house construction, which is about 2.5 times more expensive than a traditional boiler house. Other disadvantages include the large volume of this kind of fuel and – in the case of dump gas – potential fire threats (**Kompała-Bąba** and **Błońska** 2005).

In 2000 the share of renewable energy in the world’s primary energy balance was 13.8%, with biomass constituting nearly 80% of this volume (11% in the global energy output).

## Power industry and natural environment

All forms of activity performed within the energy production system have some effects on the natural environment, and generally, these are negative effects. By utilizing environmental resources (fuels, water, air) and by discharging the products of processing (such as fumes, solid, liquid and radioactive waste, and heat generated in cooling processes) back to the environment, humans disturb the existing ecological balance of the atmosphere, water bodies, and soil. If the effect of the system is small, the nature is able to reduce those negative influences. Otherwise, however, irreversible environmental changes occur, affecting all the living organisms in the ecosystem (**Szymczyk** 2005).

The natural environment is most seriously affected by fossil fuels which are utilized for electric and thermal energy production through the combustion process generating a range of pollutants (mainly air pollutants), such as: sulfur oxides, nitrogen oxides, carbon monoxide, dust, hydrocarbons, and carbon dioxide. It is estimated that energy production – both in large power plants, and for industrial and household purposes – is the major source of air pollution, generating about 90% of $SO_2$ emissions, and 60-70% of dust emissions, both in Poland and globally (**Dakowski** and **Więckowski** 2005). In Poland, economic losses resulting from the harmful effect of the entire power system (including energy consumers: industry, construction, agriculture, transportation, and individual households) on the natural environment are estimated at 12-14% of the national income (**Szymczyk** 2005). These air pollutants contribute to the greenhouse effect and acid rains, affect human health, and damage animal and plant species.

The Polish power industry is based on coal combustion, which is associated with relatively high emissions of carbon, sulfur, and nitrogen oxides to the atmosphere. Each gigajoule (GJ) of energy obtained from hard coal generates 94.6 kg of $CO_2$ emitted to the air, and the same amount of energy produced from brown coal causes an even greater emission of 101.20 kg of $CO_2$. To obtain the same amount of energy from crude oil, we "produce" 74.07 kg of $CO_2$, a and from natural gas – 56.10 kg of $CO_2$ (**Olkuski** 2005 b). Negative environmental effects of coal-fired power plants are not limited to gas emissions to the atmosphere; they also include water and soil pollution. Power plants affect the water balance through reducing local water resources, changing the physical and chemical characteristics of surface waters, and polluting surface waters as a result of sewage channeling. Soil pollution is related to the annual accumulation of thousands of tons of solid waste, including ashes and products of fumes desulfurization, which require recycling or elimination. Moreover, the process of coal mining itself affects the natural environment, producing negative changes in the landscape, land shifts and deformations, noise, pollution of rivers with salinated water pumped out from coal mines, as well as electric and magnetic fields. Most visible environmental changes are produced by brown coal mining, which usually employs the opencast extraction method. Opencast mining projects cover huge areas and, consequently, damage the existing infrastructure, lead do deforestation, and change the local hydrographic network. Brown coal extraction requires draining the deposit and channeling the removed water to the existing flows. The draining process itself leads to lowered levels of underground water and to the formation of depression cones around the mine.

The problem of oil-related environmental pollution may be analyzed at different stages of the process of oil treatment. Major threats occurring at the stage of seeking and extracting crude oil include (**Szurlej** 2005 c):

– disturbance of the hydroecological balance in the explored area, caused by seismic work,

– land deformation,

– local pollution of surface ground and soil with oil derivatives,

– contamination of underground waters, caused by migration of pollutants from the surface and from waste stockpiles,

– contamination of surface waters with pollutants from the surface installation,

– air pollution resulting from the emission of fumes from propelling engines, car engines and torches,

– noise emitted by the drilling equipment.

Oil transportation also poses threats to the natural environment. The first severe oil-tanker disaster happened in 1967, when the supertanker Torrey Canyon ran aground off the western coast of Cornwall, causing a spill of 117 thou. t of crude oil. From that accident by the end of 2000 there were over 60 more disasters, each causing a major oil spill (i.e., a spill of more than 10 thou. t of oil). Finally, at the processing stage refineries emit hydrocarbons, $SO_2$, $NO_x$, CO, $CO_2$, dust, and $H_2S$, as well as specific pollutants such as $CS_2$, phenol, ethylene oxide, glycol, methyl alcohol, acetone, ether, ammonia, sulfuric acid, CFC gases, and heavy metals. These emissions vary significantly depending on the type of refinery, kind of raw material, processes and equipment used, exploitation practices, and type of emission control.

Natural gas is commonly perceived as an ecologically pure, environment-friendly fuel. Its combustion does not generate smoke, soot or ash, and the content of pollutants in fumes is relatively low. Natural gas combustion produces virtually no emissions of sulfur dioxide and dust, and the emission of carbon dioxide is about twice lower than in coal combustion. The only threat related to natural gas treatment is the necessity to transport the material over long distances and the resulting risk of serious disasters. To illustrate the possible scale of such disasters, in early 2004 a gas pipeline explosion near Briansk in Belarus caused a nearly 10-kilometer-high column of fire and red-hot gases, forcing airliners to change their routes (**Dakowski** and **Więckowski** 2005).

Nuclear power plants are also perceived as an ecologically pure source of energy. They do not emit harmful substances to the atmosphere, they do not use noisy supplying equipment (unlike coal-fired plants), they eliminate the problem of removing and storing airborne ashes, and they occupy relatively small areas. Apart from negative public attitudes, the only major problems still to be solved involve neutralization of radioactive waste and post-exploitation land rehabilitation.

Summing up, the extraction and utilization of fossil energy carriers poses numerous environmental threats, which has been one of the reasons for seeking alternative solutions. In 1990s, when the notion of balanced growth became the basis of many countries' ecological policies, the world began to notice the potential for mass utilization of renewable energy sources (RES), which are less harmful for the natural environment and, at the same time, solve the problem of the inevitable exhaustion of fossil fuels. The utilization of such primary energy sources virtually eliminates the emission of greenhouse gases and the problem of acid rains. Other significant advantages include the availability of such resources and the possibility to supply electric and thermal energy to regions with poor infrastructure. The biggest RES-related burden to the environment is associated with the production of renewable energy installations.

Table 1 presents the effects of various renewable energy sources on the natural environment.

**Table 1**

**Effects of renewable energy sources on natural environment (Ruszkowski 1999, Podstawy... 2005)**
**Wpływ odnawialnych źródeł energii na stan środowiska naturalnego (Ruszkowski 1999, Podstawy... 2005)**

| Renewable energy source<br>Odnawialne źródło energii | Effect on natural environment<br>Wpływ na stan środowiska naturalnego |
|---|---|
| 1 | 2 |
| Solar energy<br>Energia słoneczna | • Ecologically purest RES (no pollution or noise emission).<br>Najbardziej czysta ekologicznie spośród wszystkich OZE (nie emituje zanieczyszczeń, wolne od hałasu).<br>• Minimal negative environmental effect related to equipment production.<br>W stopniu minimalnym degraduje środowisko, co jest związane z wyprodukowaniem odpowiednich urządzeń. |
| Wind energy<br>Energia wiatru | • No pollution of air, soil or water.<br>Nie powoduje zanieczyszczenia atmosfery, gleby i wód.<br>• Affects the visual aspect of landscape.<br>Wpływa na piękno krajobrazu. |

**Table 1 – cont.**

| 1 | 2 |
|---|---|
| | • Generates infrasonic noise having negative effect on humans and on animals.<br>Generuje hałas pochodzący od infradźwięków, które są negatywnie odbierane przez ludzi i zwierzęta.<br><br>• Electromagnetic disruptions (interferences with radio and television waves).<br>Powoduje zakłócenia elektromagnetyczne (zakłócenia fal radiowych i telewizyjnych).<br><br>• Threat to flying birds.<br>Zagrożenia dla przelatujących ptaków. |
| Energy of water (especially rivers)<br>Energia wód (zwłaszcza rzek) | • Each megawatt-hour generated by hydroelectric plants, rather than coal-fired thermal power plants, reduces the emission of $SO_2$ by 11 kg, of $NO_x$ by 3.5 kg, of $CO_2$ by 1100 kg, and of ashes and dust by 130 kg.<br>Każda megawatogodzina wyprodukowana w elektrowniach wodnych zamiast w elektrowniach cieplnych opalanych węglem to zmniejszenie emisji: 11 kg – $SO_2$, 3,5 kg – $NO_x$, o 1100 kg – $CO_2$, o 130 kg popiołu i pyłów.<br><br>• Changes in hydraulic conditions (e.g., flow equalization, fluctuations of water levels).<br>Wywołuje zmiany w warunkach hydraulicznych (np. wyrównanie przepływów, wahania stanów wody).<br><br>• Changes in the formation of river channels (e.g., bottom erosion, slope landslides).<br>Wywołuje zmiany w kształtowaniu się koryt rzek (np. erozja dna, osuwiska zboczy).<br><br>• Potential for intensified farming and increased ground retention.<br>Umożliwia intensyfikowanie gospodarki hodowlanej i zwiększenie retencji gruntowej.<br><br>• Reduced land area, landscape disruptions.<br>Powoduje zmniejszenie powierzchni gruntów, zakłócenia w krajobrazie.<br><br>• Positive microclimate changes, development of higher plants and lake fish farming.<br>Wywołuje korzystne zmiany mikroklimatu oraz rozwój roślinności wyższej, umożliwia hodowlę ryb jeziornych.<br><br>• Declining populations of migrating fish species.<br>Powoduje zmniejszenie ilości ryb wędrownych. |
| Geothermal energy<br>Energia geotermalna | • Environment-friendly energy generating no or minimal emissions of harmful dust and gases ($H_2S$, $CO_2$) – most geothermal power plants emit 4 times less daily amounts of sulfur compounds and about 20 times less $CO_2$ than conventional thermal power plants based on coal containing 1% of sulfur.<br>Sprzyja środowisku, gdyż w większości przypadków nie wywołuje emisji (albo tylko w minimalnym stopniu) szkodliwych pyłów i gazów do atmosfery ($H_2S$, $CO_2$) – większość elektrowni geotermalnych emituje w ciągu doby do atmosfery 4-krotnie mniej związków siarki i około 20 razy mniej $CO_2$ niż elektrownie cieplne bazujące na węglu o zawartości siarki 1%. |

**Table 1 – cont.**

| 1 | 2 |
|---|---|
| | • Risk of significant water mineralization.<br>Powoduje możliwość wystąpienia dość znacznego zmineralizowania wody.<br>• Minimal damage to the natural environment associated mainly with the drilling work (e.g., threat of local soil settlement, bothersome buzzing sound, and local tectonic shocks).<br>Wywołuje minimalne szkody w przyrodzie związane głównie z prowadzeniem robót wiertniczych (np. niebezpieczeństwo lokalnego osiadania gruntów, występowanie uciążliwego szumu oraz lokalnych wstrząsów tektonicznych). |
| Biomass energy<br>Energia biomasy | • Compared to fossil energy carriers, the utilization of biomass as an energy source is characterized by: no extra emission of $CO_2$, compared to coal – lower emission of $NO_x$, very low emission of $SO_2$, and lower dust emission.<br>Energetyczne wykorzystanie biomasy wyróżnia w porównaniu ze spalaniem kopalnych nośników energii: brak dodatkowej emisji $CO_2$, w porównaniu z węglem mniejsza emisja $NO_x$, bardzo mała emisja $SO_2$, mniejsza emisja pyłów.<br>• Possibility to utilize animal and plant waste.<br>Umożliwia utylizację odpadów roślinnych i zwierzęcych.<br>• May contribute directly to intensified agricultural production, providing natural fertilizers obtained in the process of biogas production.<br>Może się bezpośrednio przyczynić do intensyfikacji produkcji rolnej, dostarczając naturalny nawóz po procesie produkcji biogazu.<br>• Opportunity to develop agricultural areas unsuitable for food production – by launching biomass plantations.<br>Daje możliwość zagospodarowania obszarów rolniczych nie nadających się do produkcji środków spożywczych dzięki uprawom roślin energetycznych. |

## Economic aspect of utilization of energy sources

It is commonly believed that fossil fuels utilization is the only cost-effective form of energy management. According to this view, production of electric power and thermal energy from renewable resources may only bring about ecological advantages, and perhaps new employment opportunities or a chance to postpone the exhaustion of fossil fuels, but does not generate any financial profit. So what can be done to ensure that projects utilizing renewable carriers for energy production become economically profitable, which would lead to popularization of such energy sources?

The first step toward resolving this issue should involve including the overall ecological cost – rather than only direct expenditures on mining damage removal, fuel refinement, exhaust gas treatment, and environmental fees – in the economic calculation concerning the production of energy from fossil fuels. Today, broadly understood environmental losses – such as regional and continental pollution with gases and dust or the effects of soil, inland water, and sea water pollution – are not compensated, which has a negative effect on the natural environment and on the economy. Hidden expenses incurred by the government and individual citizens include (**Ekonomiczne...** 2005):

– government subsidies for the industry, e.g., for modernization of equipment,

– research programs in the area of conventional power industry,

– coal transportation over long distances,

– reclaiming slag heaps, utilization of dangerous and harmful waste (such as nuclear fuel), and repairing failures and leaks (e.g., failures of oil or gas pipelines or oil spills from tankers),

– removing the effects of crop failures and floods,

– business units' operation in contaminated environment,

– increased hospitalization and disability allowances associated with health deterioration resulting from exposure to harmful emissions.

If all these expenses (which are partly immeasurable) were included in the overall cost of obtaining energy from fossil fuels, energy from renewable sources would turn out economically competitive, as the prices of renewable and conventional energy would become comparable. The current prices of heat (central heating), gas, and electric power do not reflect the overall cost of their production, which is why realistic, unsubsidized prices of energy obtained from renewable sources are unable to compete with state-subsidized prices of conventional energy.

The major barrier to the development of renewable energy involves high expenditures on research and construction of equipment. Despite low operating cost, the payback period is relatively long. The situation will improve with technical and technological progress in obtaining renewable energy, and with general public's – and entrepreneurs' in particular – increased awareness of the inevitable exhaustion of non-renewable energy carriers. Another significant obstacle hindering the development of renewable energy is the educational barrier and the related information barrier. Due to ignorance or only vague knowledge about possible effective utilization of renewable energy sources, the Polish society has failed to show respect for energy through using alternative fuels. The information barrier applies virtually to the whole society, including potential investors and consumers of renewable energy. Higher demand for renewable energy installations would lead to their increased production, which – in the long run – should result in reduced production cost (consistently with the economics of scale).

The design and implementation of renewable energy installations will continue to be expensive for the next several years. Therefore, it seems necessary to financially support those interested in installing such equipment. These projects may be supported with state budget funds (direct subsidies, credit subsidies, loan guarantees, investment tax relieves, etc.); by Ekonfundusz (EcoFund), BOŚ (Environment Protection Bank), and the Fund for Global Environment; or with EU money coming from structural funds, the Cohesion Fund, or special EU programs such as Altener (**Kompała-Bąba** and **Błońska** 2005).

Poland may also follow the example of other EU countries which use their own mechanisms of supporting the development of renewable energy sources at the national level, such as: investment incentives, tax exclusions, tax deductions or tax rebate, as well as subsidizing wholesale prices, which is the most frequently used support mechanism. Subsidizing the wholesale price involves providing direct or indirect financial support for each energy unit supplied and sold by renewable energy producers. Depending on national regulations, the solutions applied in different countries show a substantial diversity. Subsidy systems may be categorized into two groups: supply quota and guaranteed fixed prices. The quota systems are used in countries including Ireland, The Netherlands, the UK, and Poland. There are two major mechanisms operating within such systems – tender programs and the so-called green certificates. Within the tender procedure, a series of tenders is announced for the supply of renewable energy, which is then sold to local distributors at the price determined through the tender. The cost of the surplus resulting from energy purchase is transferred to the end consumer in the form of a special deduction. The green certificates mechanism is based on selling renewable energy at market prices. At the same time, all consumers are obliged to buy certain quantities of "green certificates" from renewable energy producers. A percentage or quantitative norm is determined for overall consumption. Because consumers want to buy the certificates at the lowest possible price, a secondary green certificate market develops, on which renewable energy producers compete with each other to sell the certificates (**Bućko** 2006).

Data collected in the late 1990s showed the following pattern of investment outlays (in US dollars per 1 MW) on installations utilizing renewable and conventional energy sources, and of the energy production cost (in US dollars per 1 kW·h) (**Ruszkowski** 1999; the first amount concerns investment, and the other – the production cost):

1. Non-conventional (renewable) power plants:

– small hydroelectric plants: 1.9 m, 8.6-10.8,

– wind turbines: 0.9-1.8 m, 4.1-8.0,

– geothermal plants: 3.5-4.0 m, 5-7,

– low-power thermal heliostats: 15.0 m, 14.8 (thermal), 20.0 (photovoltaic),

– biomass and biogas: investment outlays depend on the type of fuel (straw, timber, woodchips) and the combustion technology; 8-15 (biomass), 4.4-7.0 (biogas),

2. Non-renewable (conventional) thermal power plants:

– coal-fired power plants: 0.9-2.3 m, 6.0-8.2,

– oil-fired thermal power plants: ≈0.8-1.5 m, 4.8,

– gas-steam thermal power plants: 0.6-1.2 m, 6.0,

– existing nuclear power plants: 1.6 m, 15.1,

– newly constructed nuclear power plants: 1.3-2.8 m, 3-5.

To sum up, improved competitiveness of renewable energy sources – as compared to conventional sources – may be achieved through:

– including external expenses in the overall economic calculation,

– raising the ecological awareness in the society, which will be reflected in a larger number of entrepreneurs interested in renewable energy installations,

– increasing the scale of RES technologies to reduce investment per unit,

– reducing investment outlays through improved availability of technical infrastructure (e.g., connecting to the power network),

– reducing the cost of investment plan development and expanding the market of developers, support agencies, and professional consulting companies,

– providing more opportunities to obtain financial support at the stages of planning, implementation and operation of equipment for renewable energy production – both from domestic and international funds,

– developing synergic methods of renewable energy management and building RES systems based on the cogeneration principle, utilizing both conventional and renewable energy sources (in the proportion of one to eight, respectively).

# Conclusion

It is estimated that by 2050 the global human population will have grown to about 10 billion, accompanied by at least a two-fold increase in the consumption of primary energy carriers. Given the exhaustibility of fossil resources, growing environmental threats, and the related increase in ecological awareness, it has become necessary to turn toward alternative resources. Current trends emphasize the development of renewable energy sources, which, however – though clearly environment-friendly – require large capital investment. Supporters of conventional energy do not question the substantial reduction of environmental pollution through the use of renewable energy sources. Rather, they point to problems such as limited availability of such resources and the expensive implementation of RES installations. However, long-term analyses predict that in the next 10 to 15 years differences between the prices of conventional and renewable energy will disappear. This will be possible, if environmental expenses are included in the overall economic calculation of energy production, and if technological progress contributes to cheaper RES installations, characterized by lower levels of material and energy consumption. Another way to reduce the cost of renewable energy is through combining different sources within a single energy production complex. Cogeneration increases the operating effectiveness of energy systems, reduces the investment cost of the expansion of industrial power networks, and minimizes transmission losses through shortening the distance between the energy source and the end consumer and through ensuring continuous energy supplies. Consequently, it seems just a matter of time before renewable energy sources become economically competitive.

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## ASPEKT EKOLOGICZNO-EKONOMICZNY WYKORZYSTANIA ŹRÓDEŁ ENERGII KONWENCJONALNEJ I ODNAWIALNEJ W PROCESIE GOSPODAROWANIA

### Streszczenie

W procesie gospodarowania ważnym czynnikiem umożliwiającym właściwą realizację zadań jest wykorzystanie energii. Źródłem energii pierwotnej są paliwa kopalne, które mają charakter nieodnawialny, oraz paliwa zaliczane do grupy tzw. odnawialnych źródeł energii (OZE). Rozwój nośników odnawialnych, czyli wiatru, wody, słońca, biomasy i źródeł geotermalnych, jest związany z degradacją środowiska, do której przyczyniła się gospodarka paliwami nieodnawialnymi (np. węgla, ropy naftowej). Główną barierą w rozpowszechnieniu OZE jest ich, jak do tej pory, ekonomiczna nieopłacalność, związana z wysokimi kosztami inwestycyjnymi. Korzystanie z nośników odnawialnych na większą skalę to dopiero przyszłość, która zależeć będzie od cen tego rodzaju energii, a także od technologicznych możliwości wykorzystania potencjału OZE. Paliwa kopalne będą, i po części już są, zastępowane energią odnawialną, ale przy obecnych cenach i rozwoju technologii energetyka konwencjonalna zajmuje czołowe miejsce w energetyce światowej i krajowej.