ENERGY ALTERNATIVES FOR EUROPE

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In the current era the electric energy is „the most processed" crude, without which any modern society could not develop further and even function as it is. But while the demand for electric energy is growing exponentially, the easily available energy sources in crudes such as coal, oil and natural gas are being increasingly depleted, which in consequence leads to rapidly raising prices of natural resources on world markets and shifting from strategic to dominant position of the importance of energy policy as a factor determining international relations and geopolitics. Moreover, the excessive burning of carbon compounds results in the greenhouse effect responsible for general climate warming and destabilization which manifests in reduction of thickness and surface of the ice covered caps on both of the North and South Poles, thus raising the level of oceans and seas, in fierce hurricanes, typhoons, floods, as well as droughts and severe heat waves. The growing desert areas in Asia and Africa are being witnessed and the African great lakes such as Lake Chad and Lake Victoria start to quickly reduce its surfaces. It is estimated that in about 50 years the level of the oceans could rise by up to a half of a meter, which implies that huge areas of the coasts of continents will be under water, or will be permanently threatened by floods. This applies, above all, to densely populated areas of the deltas of great rivers of Asian countries and the subtropical Pacific and Indian Oceans island countries. Currently, those regions are inhabited by about 100 million people, and within the estimated half of a century this population of endangered areas is expected to increase significantly. The scale of the risks arising from the unnatural climate changes has urged the international community to adopt the *United Nations Framework Convention on Climate Change* during the Earth Summit in Rio de Janeiro in 1992 and to signing of the *Kyoto Protocol* in December 1997, which is a supplemental document to *the Convention. The Protocol* requires all ratifying countries to reduce emissions of greenhouse gases on average by 5.2% to 2012 in relation to the level of 1999. Further the reduction of CO_2 emissions for the countries of the European Union was agreed at 8%. A priority has thus been set on reducing the emission of carbon dioxide into the atmosphere, which is both a product of living fauna and flora, as well as the effect of industrial development of civilization. Metallurgy, production of construction materials, fertilizers, communication industry, and above all, energy based on combustion are the main perpetrators of the CO_2 mass entry into the atmosphere. The easiest way to reduce carbon dioxide emissions would therefore be a broader use of nuclear energy and the development of energy production infrastructure based on the socalled renewable energy sources (RES).

Broader use of nuclear energy in countries of the European Union has more opponents than supporters. This is a common trend not only manifesting in Europe but also worldwide. The negative attitude of society and policy makers does not only result from the incident at Chernobyl in 1986, but also from plain economic calculations. General withdrawal from nuclear energy in recent years has caused a sharp increase in costs associated with the storage of spent fuel rods and other radioactive waste materials. At the core of this phenomenon lies the threat of terrorism. Latest intelligence reports disclosed that countries such as India and Pakistan obtained part of the radioactive materials required for developing their nuclear arsenals from used nuclear fuel rods, in which still remained about 2% of uranium isotope U-235. The rods were often utilized and prepared for secured storage by private companies that due to economic effectiveness performed certain operations in its subsidiaries in third world countries, where the intelligence services of these countries were actually taking over the strategically dangerous U-235 isotopes. In addition all other kinds of more easily accessible radioactive waste materials originating from nuclear power plants (e.g. used radioactive shields, exhausted reactor construction elements, etc.) could be potentially used by terrorists to manufacture a socalled „dirty bombs", i.e. bombs with classic explosive material shielded by or containing radioactive material. Detonation of a „dirty bomb" could spread radioactive materials in relatively large ranges, contaminating, causing panic and effectively paralyzing normal functioning of densely populated metropolitan and industrial areas.

For certain radioactive isotopes of elements constituting the waste of nuclear power plants, half-life decay times are counted even in thousands of years. High construction costs of specially designed landfills for storage of radioactive waste and difficulties in predicting of their half-life decay times (determining necessity for constant monitoring and maintenance of the security of storages) are main arguments of environmental groups opposing nuclear energy power. This is an argument so effective that it has convinced the societies and energy policy makers in most of the developed countries. The survey performed in 2007 by the Eurobarometer, shows that only 20% of EU citizens support development of the nuclear energy, while 37% are clearly against this direction. Very recently, however, there can be observed a radical turnabout from informational consensus on nuclear energy presented in Western mass media and increase of propaganda from the advocates of nuclear energy usage. This is due to the recent purchase by Western corporations of huge deposits of uranium ore in Kazakhstan and further made large investments in the search for outlets for uranium. Although strong mass media campaign promoting back to the “clean energy”, led by the world biggest French nuclear energy corporation – Areva and president Sarkozy, the purchase may be a missed investment because the process of construction of a nuclear power plant based on fission of uranium lasts for a relatively long time that is about 10-15 years. In Europe, only France obtains about 90% of electricity from nuclear power plants, but they are relatively new facilities. The United States on the other hand for more than 15 years has not built any new power plant, and as a matter of fact closed several existing. Currently in Europe there are two reactors under construction – Flamanville in Normandy (from the December 2007) and Olkiluoto-3 in Finland (from 2005), which are realization of the French prototype project of the EPR (European Pressirised Reactor), but numerous construction flaws and rising costs connected to them postpone the perspective of finishing works on time.

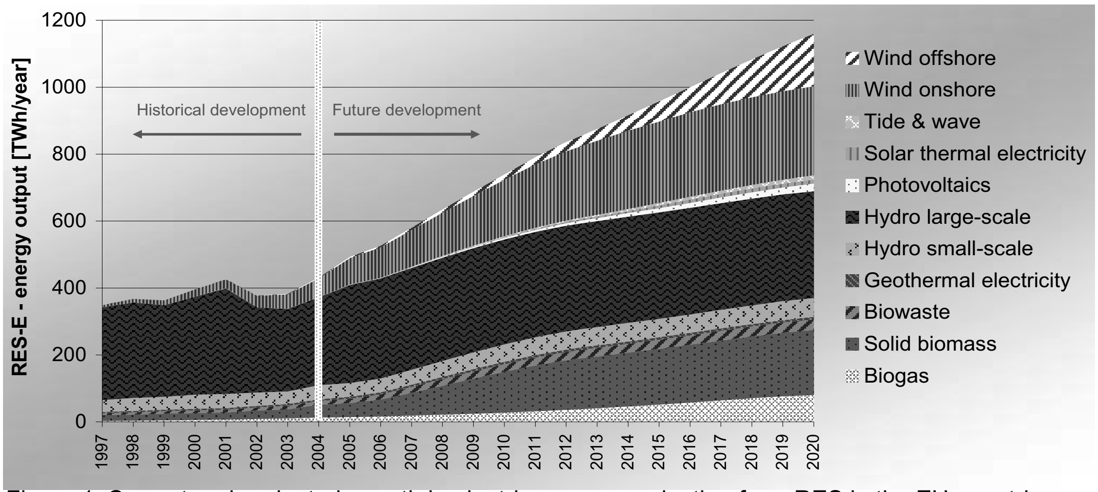

Figure 1. Current and projected growth in electric energy production from RES in the EU countries.

By contrast, in the near term, it is possible that the first nuclear power plant based on nuclear fusion of deuterium and tritium – isotopes of a hydrogen (an element very common in nature, e.g. constituting oceans along with oxygen) – will be at last successfully built. Fusion seems to be the most promising and simultaneously ecological source of cheap electric energy. This requires, however, the construction of extremely complex and expensive construction called a tokamak (the Russian acronym: TOroidalna KAmiera z MAgnitnymi Katuszkami - toroidal chamber with magnetic coils). The largest installation of this type will be ITER (i.e. the International Tokamak Experimental Reactor) currently implemented by countries such as China, India, South Korea, Russia, the European Union and the United States. ITER is being carried out at Cadarache (southern France), and its construction is scheduled to be completed in 2015. The device is intended to help solve technical problems with the construction of the first commercial power plant based on nuclear fusion (as for now there has been no production scale nuclear fusion tokomak built that would have a positive energetic balance, i.e. producing more energy from the fusion process than indeed using to initiate and control this fusion process). Nevertheless it is still not clear whether the ITER will be successful or not, it is clear that if the implementation difficulties of the nuclear fusion will be overcome (nuclear physicists and constructors struggle with those for over 50 years with degrading optimism) the existing economic and ecological problems of nuclear energy connected to preparation and management of dangerous nuclear fuel and waste will disappear. In the future power plants based on nuclear fusion, the isotope of hydrogen – tritium will be produced in the reactor in a closed cycle. There will also be no radioactive waste products. Only a very small quantity of tritium will be needed for the operation of the plant, which could be relatively easily obtained from the common hydrogen. The shielding of the interior of the plasma chamber will be radiated during the operation of the reactor by the neutrons emitted in the nuclear fusion process. However, by using appropriate materials, one can get overcome this problem reducing the recycling time to a period of roughly 100 years (thanks to a relatively brief half-life nuclear decay time). The tokamak being built in Cadarache is planned to acknowledge the possibility of carrying out commercial engineering applications from often very fragmentary results of laboratory research on nuclear fusion.

Harnessing the technology of producing electric energy in a process of nuclear fusion and its dissemination in international societies is estimated to be successful in the half of the current century, i.e. too late to implement the agreements of the Kyoto Protocol. Hence the leading countries of the EU, implementing policy of energy sources diversification and environmental protection, began the realization of the programme of obtaining electricity from renewable energy sources (RES). The hitherto prevailing course and the future forecast of the RES usage is shown in the Figure 1.

The diagram implies that still the largest producers of electric energy in the EU are hydroelectric power stations, however possibilities of further construction of such power plants in the EU are virtually exhausted and the hydroelectric power plants employing Oceanic tides, built in France

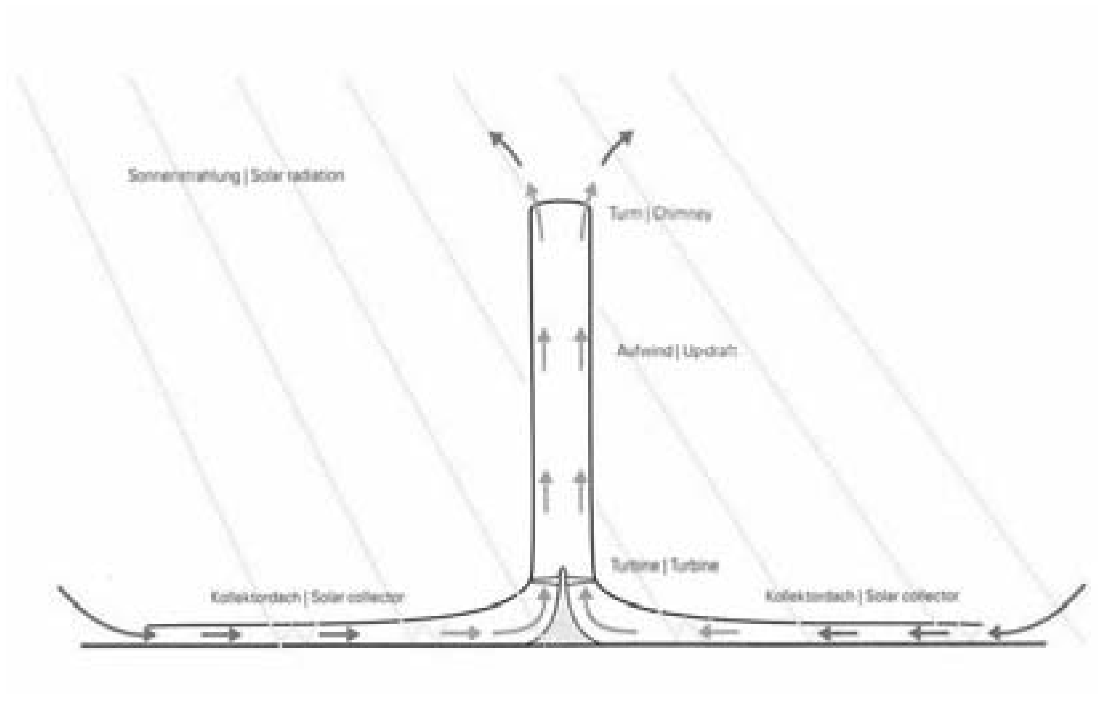

Figure 2. The operation scheme of a power plant based on thermal air flow

and Scotland, are so far only a prototype installations. Currently, the most effective renewable energy sources are wind power plants and power plants based on the combustion of biomass and biowaste. Technologies based on combustion, however, did not result in reducing of the quantity of CO_2 emitted to atmosphere, although at the present stage of technological development, they are the easiest and the cheapest solutions. The construction of wind power plants is currently the fastest-growing branch of renewable energy industry in Europe because of the relatively low costs of installation, low level of technological advancement and potentially unlimited localization availabilities. In the EU the largest installed capacity of all deployed wind power plants in 2006 was Germany (20622 MW), followed by Spain (11615 MW), Denmark (3136 MW), England (1716 MW) and Portugal (1715 MW). Although wind power plants obviously do not emit CO_2, their construction often encounters strong opposition of local communities afraid of the destruction of the landscape aesthetics, as well as environmental organizations pointing to the negative impact of windmills changing the local microclimate and causing migrations of many species of birds from their natural habitats. This greatly reduces the possibility of localization of these power plants in the countries of Western Europe, which is why in recent years, more and more frequently they are built on the platforms located on seas and oceans. A major disadvantage of wind power is also a lack of production of electricity at too weak or too strong winds. The smallest development in the EU countries is recorded in the use of photovoltaic and hydrothermal energy, being a result of the large investments needed to achieve cost-effectiveness.

Surprisingly good effects may be obtained in realization of a quite simple and ingenious project of the production of electric energy utilizing phenomenon of thermal air flow. The first installation of this type was built in 1982 in Manzaranes (Spain). The principle of operation is shown in the Figure 2 . Movement of hot air warmed by the sun under a hanging roof of a solar energy collector is directed to a tall chimney driving a slow motion wind turbine with horizontally placed blades thus producing electricity. The plant does not emit any exhausts and moreover it's very simple construction and maintenance determine relatively small investment. A prototype power plant of based on thermal air flows in Manzaranes has an area of 44 000 m2 and a 200 m tall chimney with stiffened rings of folded metal sheet, supported by a system of ties. The Spanish results were so promising that in Midura (Australia) a first commercial power station of this type with a capacity 200 MW have been designed – the construction process is to be completed by the end of 2008.

At about the same time there emerged another interesting idea to build an „energy strip" in a form of large-scale installation exploiting the phenomenon of thermal air flow in deserts of the Arabian Peninsula and in Sahara from Egypt to Morocco, which could become an important source of energy for the countries of the European Union, as well as the countries of the region. Localization of this "energy strip" power plants in the Sahara Desert near the shore of the Mediterranean Sea would allow for relatively easy transport of the energy to South Europe by underwater cables. It would also allow the use of energy produced in this constructions to power installations of sea water desalination or in attempts of pumping water from the „underground sea" located below the surface of the Saharan Desert. Low installation costs, the possibility to provide land arrangement and development plans for the massive desert areas, the overall environmental performance and the possibility of the participation of private investors in the construction of a large-scale installations of power plants utilizing thermal air flow make the idea of the „power strip" extremely attractive energy alternative to the European Union. The biggest barrier to implementation of the project is a lack of political agreement of the countries of the region of North Africa, as well as other producers of energy raw materials. Although the proWestern African countries possessing small deposits of raw materials, such as Tunisia, Morocco and Egypt are interested in the project, the biggest suppliers of oil to the EU from the African continent – i.e. Algeria and Libya are strongly determined to express their opposition. The opposition is obviously also faced from Russia, which plans to supply natural gas by the South Stream pipeline (through the territory of Bulgaria and Serbia, with already settled political agreements) to Italy, southern France and Spain. A major obstacle in the construction and subsequent use of efficient energy producing installations of this type is also a potential terrorist threat from Islamic fundamentalists, as well as the general political instability of the region and a lack of African infrastructure development. From this perspective, the most realistic option seems to be the initial inclusion in the project only of Morocco and Tunisia and transferring energy to power the south of Spain and the south of Sicily. Nevertheless we should not abandon the attempts to implement the whole „power strip", which would eventually confirm the predictions of H. MacKinder from the half of the twentieth century of an extraordinary energetic wealth of the Sahara and thus its geopolitical significance.

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Termodynamika skraplania gazu ziemnego w ujęciu teorii bilansów

W pracy podjęto próbę zastosowania teorii bilansów w zagadnieniach termodynamiki skraplania gazu ziemnego celem uzyskania efektu jednolitego sformalizowanego opisu tego procesu, umożliwiającego opracowanie efektywnej metodyki termodynamicznego projektowania urządzeń skraplających gaz ziemny dla dowolnego systemu skraplania. Dla osiągnięcia tego zamierzenia przedstawiono zastosowanie metod teorii bilansów w następujących zagadnieniach:

— termodynamiki fazy gazowej wieloskładnikowej
— substancjalnego bilansu zasobu energii wewnętrznej (EW) dla wielkości ekstensywnych (WE)
— substancjalnego równania energii wewnętrznej (EW) dla wielkości intensywnych (WI)
— uogólnionego bilansu zasobu energii wewnętrznej (EW) dla układów otwartych
— bilansu zasobu entalpii dla urządzeń przepływowych w tym dla nieodwracalnych obiegów prawo- i lewobieżnych.

Ponadto wprowadzono i zdefiniowano pojęcia, które pojawiły się jako konsekwencja zastosowania teorii bilansów w termodynamice. Pojęcia te odnoszą .się do znanych i stosowanych w termodynamice i są zazwyczaj ich uogólnieniami. Między innymi zdefiniowano.

— zredukowaną indywidualną stałą gazową
— funkcje termodynamiczne entalpii uogólnionej oraz uogólnionej entalpii swobodnej
— uogólnione ciepło właściwe substancji.

W teorii bilansów pojęcie zasobu należy do zbioru pojęć pierwotnych. Definicje wielkości ekstensywnej (WE) i intensywnej (WI) określone są przy użyciu pojęcia pierwotnego jakim jest zasób. Umożliwiają one formułowanie w prosty i przejrzysty sposób równań bilansowych dla różnych wielkości fizycznych, spełniając tym samym rolę porządkującą w rozważaniach termodynamiki fenomenologicznej, a zatem również w zagadnieniach termodynamiki skraplania gazu ziemnego. W pracy konsekwentnie stosowano pojęcie zasobu i jego gęstości. Wykorzystując wyżej wymienione pojęcia, definicje i twierdzenia, opracowano metodykę termodynamicznego projektowania instalacji skraplania gazu ziemnego (LNG) w ujęciu teorii bilansów, którą zilustrowano na przykładzie termodynamicznego projektu instalacji skraplania gazu ziemnego (LNG) metodą kaskadową w układzie trójstopniowym. Wyniki obliczeń uzyskane w procesie termodynamicznego projektowania instalacji skraplania gazu ziemnego (LNG), przy wykorzystaniu zaproponowanej w - pracy metodyki termodynamicznego projektowania instalacji skraplania gazu ziemnego (LNG) w ujęciu teorii bilansów, wskazują na jej jednoznaczność (algorytmizacja procesu projektowania), skuteczność (zbieżność procesów iteracyjnych) i efektywność (optymalizacja procesów obliczeniowych).