Lucjan Kurzak

Ecological Aspects of Energy Sector Development

Economic growth and rise in population impose increased production of energy. Limited conventional energy resources and their negative impact on the environment in the case of traditional processing cause the necessity to search for new sources and technologies of processing and use of energy. Cooperation of nations in unanimous limitation of pollution emissions and, in consequence, taking measures for prevention of world climate change must become an essential element of energy policies.

Keywords: energy, ecology, pollution emissions.

I. ENERGY – ITS ROLE AND IMPORTANCE

Energy, in terms of sustainable development of each country and the whole world, is a factor which enables progress. Acquisition, processing and use of energy is one of the reasons for environmental pollution and a threat to human health [2,3,4].

Ecological consequences of use of energy have been known worldwide for long time. Burning wood has led to deforestation in many areas of the world. As soon as in early periods of industrialization, huge local pollution to air, water and soil occurred. Importance of energy for improvement in standard of life is unquestionable; however, production and use of energy are closely related to emissions which cause degradation of natural environment. Such a degradation poses threat to human health and life quality and contributes to greenhouse effect which, in consequence, leads to climate changes around the globe.

Intensified development of industries, appearance of huge urban areas, rise in energy sources extraction volume, increase in production and use of energy, particularly in first decades after the Second World War have cause enormous degradation of the environment, both on a local and global scale.

Main hazardous substances being emitted after burning of fossil fuels in energy sector include: sulphur oxides, nitride oxides, carbon dioxide, furnace waste and dust [1,2].

On a wider scale, the negative impact on environment typically manifests in:

acid rains caused by excessive emissions of SO_2 and NO_2, causing degradation of forests and soil, life dying out in rivers and lakes, deterioration of health state of the people and living organisms,

ozone hole which exposes the earth to ultraviolet radiation causing increased morbidity rate,

greenhouse effect which causes climate change worldwide.

II. CO_2 EMISSIONS AND GLOBAL WARMING

The most important and most nagging problem on a global scale is reduction in CO_2 emissions, which have been on the increase over past decades. According to most of scientist, growing warming of the world atmosphere is caused by greenhouse gases emissions, particularly CO_2 emissions. In consideration of the above mentioned, in December 1997 representatives of many governments met in Kyoto at UN conference where a number of decisions towards limitation of CO_2 were made. These arrangements were made in the document called 'Kyoto Protocol', whose goal is limitation of greenhouse gases emissions to the atmosphere during 2006-2012 by 5.2% in relation to the state from 1990. The Protocol has been in force since 18 February 2005 after being signed by 55% of signatory nations.

It is unquestionable that CO_2 amount emitted to the atmosphere on a global scale almost doubled during the period of 1971-2004 – it increased from 13.96 billion tons in 1971 to 22.64 billion tons in 2000 and 25.64 billion tons in 2004 [7] (Tab. 1).

Tab. 1 Emissions of CO_2 in 2004 with division into regions of the world [7]

Region	CO_2 emissions (billion tons)
OECD countries	12.91
Middle East	1.18
Countries of former USSR	2.31
Non-OECD European countries	0.27
China	4.76
Asia counties (without China)	2.50
Latin America	0.90
Africa	0.81
Total	25.64

Limitation of CO_2 emissions means, to energy sector, a radical change in energy policies. The attempts are being made to reduce consumption of fossil fuels, mainly limitations of coal consumption – particularly in old, low-capacity power plants, where coal is still a fundamental fuel for production of electricity. This means necessity for world energy sector to bear huge expenses and causes considerable increase in energy prices.

Concerning impact of CO_2 emissions on warming of the atmosphere, there have also been voices from a part of scientists that human activity does not necessarily have to be a reason for rise in global temperature. World has always undergone periods of warming and ice ages. Thus, it can be speculated whether a next age of global warming have just begun.

III. MACROECONOMIC AND ENERGY PROGNOSES OF THE WORLD

Major motive powers for energy demand and world energy sector development include: economic growth expressed by Gross World Product (GWP) and population growth rate.

According to recent population forecast prepared by the United Nations and accepted by the International Energy Agency (IEA) in 2004, world population will increase from 6.2 billion in 2002 to 8.1 billion in 2030.

The International Energy Agency determined in their reference scenario a world economic growth, expressed in average annual percentage of GWP at the level of [11]:

- 3.7% for 2002-2010,
- 3.2% for 2010-2020,

– 2.7% for 2020-2030.

It was estimated that in each world region this increase will be considerably differentiated – higher in developing countries (particularly in China and India) while relatively low in OECD countries and the countries which are undergoing transition.

Considerable changes in the structure of primary energy demand are assumed in the forecast until 2030 – coal contribution will reduce while natural gas share will rise (Tab. 2). Moreover, reduction in nuclear energy contribution is also assumed, although recent years have seen a renaissance in views on nuclear energy. Due to this fact, rise in nuclear energy contribution should rather be expected with simultaneous limitation of fossil fuels. Considering limited resources of natural gas and its high prices, forecast of its demand is questionable.

Tab. 2 Usage and Forecast for primary energy demand in 2002-2030 [11]

Energy source	Mtoe		2002=100	Structure, %	
	2002	2030		2002	2030
Coal	2389	3601	151	23.4	22.0
Crude oil	3531	5604	158	34.6	34.9
Natural gas	2190	4130	189	21.5	25.3
Nuclear energy	692	764	110	6.8	4.7
Water energy	224	365	163	2.2	2.2
Other renewable sources	1174	1861	159	11.5	11.4
Total	10200	16325	160	100.0	100.0

It was accepted in IAE forecast that world production of electricity will be doubled, from 16.1PWh in 2002 to 31.7PWh in 2030 [11]. Average annual growth will amount to 2.4%, which means that rise in electricity production will be much faster than rise in primary energy consumption. Production of electricity in OECD countries will rise from 9.7 PWh in 2002 to 14.2 PWh in 2030 by ca. 48%. However, in non-OECD countries, this production will increase over three times from 4.8 PWh in 2002 to 14.9 PWh in 2030. Particularly sharp electricity production growth will be reached by China, India and countries of Africa.

Despite high electricity production growth rate in non-OECD countries, per-capita production in these counties in 2030 will still be ca. 5-times lower than this index for OECD countries. In OECD countries, per-capita production index in 2030 will amount to ca. 11.0 MWh, in non-OECD countries – ca. 2.3 MWh, including China 3.8 MWh and India 1.4 MWh.

World forecast for electricity production with division into main regions is presented in Table 3.

Tab.3. Forecast of electricity generation to 2030 by regions [11]

Region	TWh			
	1971-2002	2002-2010	2010-2020	2020-2030
OECD	9757	11302	12941	14243
of which				
- North America	4809	5580	6417	7154
- Europe	3271	3743	4272	4674
- Pacific	1677	1978	2252	2415
Transition countries	1485	1745	2134	2469
of which				
- Russia	889	1028	1200	1361
Developing countries	4832	7139	10677	14945
of which				
- China	1675	2653	4018	5573
- East Asia	653	980	1490	2032
- India	598	878	1362	2004
- Middle East	512	679	940	1214
- Africa	480	671	1028	1583
- Latin America	809	1108	1567	2149
World in total	16074	20185	25752	31657

According to IEA forecast, in order to achieve the assessed production levels, it will be necessary to ensure rise in world installed capacity from 3700 GW in 2002 to 7300 GW in 2030. In consideration of the necessity to withdraw ca. 1/3 of current capacity, there will be a need for creation of ca. 4800 GW of new capacities.

IV. FORECAST OF WORLD CO_2 EMISSIONS FROM FOSSIL FUELS

The forecast rise in CO_2 emissions is closely related to burning of fossil fuels, whose amounts for 2002-2030 were presented in Tab. 4.

In the forecast period of time, CO_2 emissions will rise from 23.6 billion tons in 2002 to 38.2 billion tons in 2030, i.e. by 62% with rise in demand for fossil fuels by 64%.

Tab.4 Usage and Forecast of demand for fossil fuels and CO_2 emissions in 2002-2030 [11]

Fuel	2002		2030	
	Consumption Mtoe	CO_2 emissions, Mt	Consumption Mtoe	CO_2 emissions, Mt
Coal	2389	9023	3601	13866
Crude oil	3676	9637	5766	15035
Natural gas	2190	4919	4130	9313
Total	8255	23579	13497	38214

Percentage shares of fossil fuels in CO_2 emissions in 2002 and those forecast for 2030 are presented in Fig. 1.

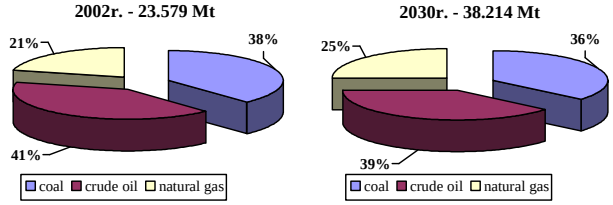


Fig. 1 Structure of CO_2 emissions according to the type of fuel [11]

As results from the above, structure of emissions will not be considerably changed. It is, however, remarkable that oil burning will cause emissions lower by ca. 32% while for gas by ca. 40% than for emissions during coal burning. This results from comparison of the forecast CO_2 emissions for burning of 1 toe of different fossil fuels, which causes:

– coal ca 3,9t CO_2/toe
– crude oil ca 2,6t CO_2/toe
– natural gas ca 2,3t CO_2/toe

World prognosis of CO_2 emissions in relation to consumption type also seems to be interesting. Contributions for each sector are presented in Fig. 2.

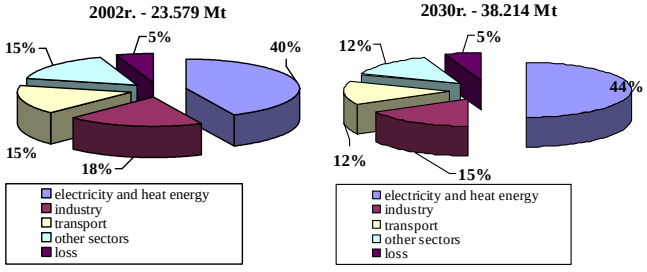


Fig. 2 Structure of CO_2 emissions according to consumption type [11]

Analysis of pie charts (Fig. 2) enables observation of insignificant structural changes which occur during the forecast period. Insignificant increase from 40 to 45% of CO_2 emissions is forecast for production of electrical and heat energy and 3% drop in industry and transport.

V. ASSESSMENT AND INITIATIVES BY INTERNATIONAL ORGANIZATIONS

Issues of perspectives and forecasts for world energy sector development, being the subject of the abovementioned analysis by the International Energy Agency (IEA), were also discussed at 20th World Energy Congress which was held in 11-15 November 2007 in Rome [1].

During the Congress, the Chairman of the Intergovernmental Panel on Climate Change, Chajendry Pachauri, presented the report from 4th May 2007 concerning reasons for the world atmosphere warming and measures which should be taken to prevent climate change. The study included a roadmap of initiatives for governments and their policies.

The roadmap for measures to be taken consists of two stages:

1. Stage I – until 2015 – lead to slowdown in emissions which cause greenhouse effect.
2. Stage II – until 2030 – stabilization of emissions levels through implementation of new technologies reducing such emissions, improvement in energy efficiency, rise in contribution of renewable sources of energy and fuels with low emissions during production.
3. Stage III – until 2050 – permanent reduction of emissions i.e. energy policies which promote low gas emissions, particularly CO_2, through implementation of technologies with 'zero emissions', especially development of nuclear energy sector and hydrogen-based technologies.

Moreover, the presentation of various reports on ecology and climate change in the world during the Congress enables to draw the following conclusions [1]:

- Human activity is held responsible for global warming; its probability is assessed at ca. 90%. Climate change phenomenon was discovered ca. 100 years ago and is connected with widespread industrialization, rise in population, deforestation, increased energy production – from fossil fuels in particular – and popularization of transport using combustion engines. As a result, increased amount of gases are released to the atmosphere, particularly CO_2, which intensifies greenhouse effect and leads to changes in climate system around the globe.
- According to the forecast before last century, concentration of CO_2 can reach 800-1200 ppm and average temperatures will be higher by 1.5 to 4^0C as compared to present figures. This means destabilization of the climate, which will cause increased incidence of natural disasters, catastrophic draughts, hurricanes etc. Food production might also be at risk in many regions of the world. Moreover, as a result of glacier melting, level of seas and oceans will also rise, posing island-located countries at particular risk.
- Climate Convention, Kyoto Protocol and last report of IPCC show necessity for governments of world nations to take severe measures in order to limit CO_2 emissions. Thus, one of the methods of emissions reduction is a concept of capturing and storage of CO_2 emitted during fossil fuel burning in power plants, particularly in the case of coal.
- For EU countries, obligations concerning stabilization and reduction of CO_2 are essential. Reduction of CO_2 is a fundamental element of EU politics. It should be reached by changes in coal consumption in favour of natural gas and renewable, liquidation of inefficient and highly-emissive power plant equipment, development of nuclear energy sector, building of modern coal power plant solving Carbon Capture and Storage (CCS) problems.

In order to cope with environmental challenges and to ensure supply safety, the European Union takes a variety of measures for inspiration and regulation.

During EU summit in Brussels in March 2007, member states leaders signed commitment of '3x20'-ecoplan for 2020 saying that:

- 20% of energy produced in the EU will come from renewable sources
- Carbon dioxide emission will be reduced by 20% (as compared to 1988)
- Unit demand for energy per national income unit will be reduced by 20%.

These commitments result from growing awareness of threats to the natural environment coming from conventional energy sector. Thus, more and more interest in renewable sources of energy is seen in Europe and in the world.

On 23.01.2008 the European Commission accepted a project of a directive on promotion of use of renewable sources of energy. This document will be, in nearest years, a cornerstone to initiatives connected with production of green energy and investments in renewable technologies.

Fundamental elements of the package include:

- Each EU country must have their own obligatory minimum level of share of renewable sources in energy balance. In consequence, as much as 20% of energy consumed within the EU will come from renewable energy sources by 12 years.
- Changes in European system of permissible CO_2 emissions. Current levels for European steelworks, cement mills or power plants can emit as much of CO_2 to the atmosphere as they have valid permissions. They are granted the permissions for free from their governments, but in a reduced quantity. The Commission recommends that after 2013 all permissions for CO_2 emissions are sold at auctions. The auctions will be organized by each UE country.
- Considerable reduction in carbon dioxide emissions in the branches which are not involved in permission commerce. This concerns mainly transport. The reduction within the whole EU is expected to reach 10% on average. However, in case of some countries (including Poland) the Commission agreed to increase permissible CO_2 emissions in consideration of the economic growth requirements.
- Biofuels (e.g. ethanol) are expected to account for 10% of the total amount of fuels used in transport.
- New principles of public support for development of new energy technologies (e.g. technologies of capturing and storage of carbon dioxide).
- Recommendations of the Commission must be accepted by EU Council (i.e. member states' governments) and the European Parliament, which can occur at the end of 2008.

Fig. 3 presents percentage-based shares of renewable energy in total consumption in EU countries in 2006 (white fields) and those predicted in EU plans for 2020 (black bars). The figure indicates vast diversification, from several percent (United Kingdom 1.98%, Belgium 2.11%) to 30.02% in Sweden and 34.31% in Latvia. This diversification results from availability of renewable resources (water and biomass resources in the form of wood from Scandinavian countries) and tradition as well as economic and ecologic policies in the countries. Explanation for some countries having particularly low level of share of renewable sources in energy production is their geographical location, where both share of water, solar and biomass will newer play an essential role due to reduced natural resources.

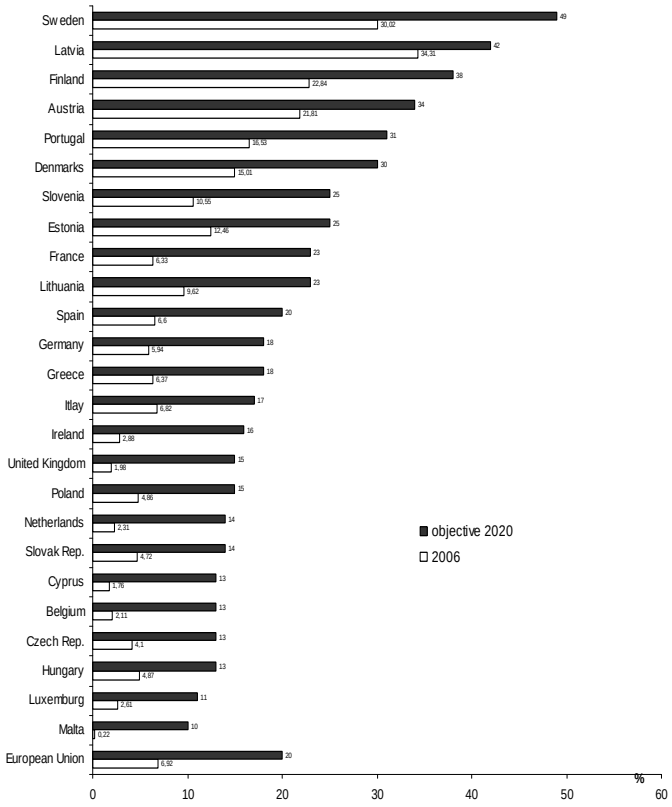
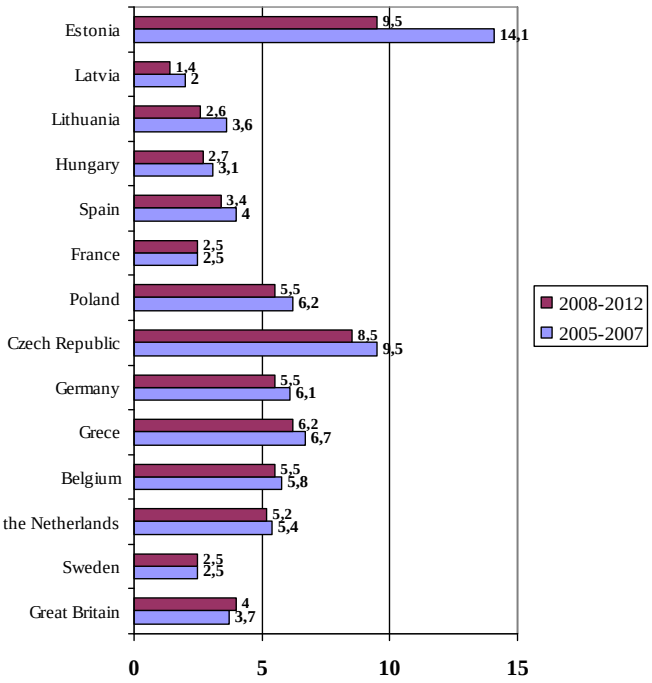


Fig. 3. Share of renewable energies in primary energy consumption of EU countries in 2006 and predicted for 2020 (in %) [8] and data from Eurostat

In consideration of the abovementioned (current production, potential, resources, economy condition, scattered resources), the European Commission proposed diversified growth in renewable energy in each EU country at the level of around 10% for countries with small potential up to almost 20% with an average of 15%. The numbers are also given in the described chart. Such a variety of efforts spread between the countries is supposed to lead, in 2020, to 20% share of renewable resources in total consumption with ca. 7% share in 2006. The increase values put forward by the Commission are still to be negotiated and must be approved by all countries and the European Council.

The result of particular measures is determination of free limit of CO_2 emissions for each EU member state. Level of CO_2 emissions per capita in each selected European countries in 2005-2007 and those allocated for 2008-2012 is presented in Fig. 4.

The figure above shows differentiation of limits for CO_2 emissions at the level from 1.4 for Latvia through 5.5 for Poland to as high as



9.5tCO_2 per capita for Estonia. Such a differentiation results from the levels of current emissions, energy sources structure, opportunities of modernization and implementation of new technologies as well as from the level of development in each EU country. It is essential, from the standpoint of each country and the whole European Union, to implement initiatives so that obligations are met. The goal is common – to protect world climate.

Fig. 4 Levels of free emissions of CO_2 determined by the European Commission [tCO_2 per capita]

Issues of reduction in greenhouse gases emissions were also discussed at last G8 summit held by the industrialized countries in Japan in July 2008. Stormy debate have led to acceptance of severe limits for **reduction in global CO_2 emissions by 50% until the half of the present century.** Everyone who cares about the future of the globe, hope that the declaration will find unanimous confirmation in practice.

CONCLUSIONS

Ensuring energy and ecological safety on a global scale requires several strategic actions:

1. Realization of energy investments of a wide range with use of nuclear energy sector and renewable energy resources.
2. Implementation of modern technologies for improved energy efficiency, both in energy production and consumption areas.
3. Implementation of ecological technologies, production of energy at minimally negative impact on the environment and thus preventing climate change in the atmosphere.

International cooperation in terms of exchange of information, energy-efficient technologies and measures for reduction in global emissions of harmful substances to the environment.

REFERENCES

[1] BICKI, Z., SOLIŃSKI, J. 2008. Rome 2007 20th World Energy Congress, Energetyka, Katowice nr 2.

[2] KURZAK L., 2006. Production and services in enterprise, Wydawnictwo Wydziału Zarządzania Politechniki Częstochowskiej, Częstochowa.
[3] PACHURA P., NOWICKA-SKOWRON M., NITKIEWICZ T., KOZAK M. 2007. Networking for Sustainability. Polish Journal of Environmental Studies Vol.16, No 3B
[4] PLECHAWSKA M., MIŁOSZ M.: Global collaborative knowledge system. Polish Journal of Environmental Studies Vol.16, No. 4A
[5] SOLIŃSKI J., 2008. Światowe rezerwy surowców energetycznych, Energetyka, Katowice nr 2
[6] Green Papers, A. European Strategy for Sustainable, Competitive and Secure Energy Commission of EU, 2006.
[7] Key World Energy Statistics 2006 OECD-IEA 2006
[8] Instytut Energii Odnawialnej, Barometr, www.ieo.pl/eurobserver
[9] Commission Communication of 7 December 2005, The support of electricity from renewable energy sources – Com/2005/ 627- final
[10] Survey of Energy Resources – 19 Edition, World Energy Council, 2001
[11] World Energy Outlook 2004 , OECD-IEA

