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Impact of inactive hard-coal mines processes in Silesian Coal Basin on greenhouse gases pollution

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ABSTRACT:

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The paper describes air pollution problems in Poland, especially in the urban areas with high levels of SOx, NOx particulates and carbon dioxide. Particularly very high is concentration of sulfur dioxide and particulates. Emission rates per-capita and per unit of GDP have been several times that of neighboring western countries, although the levels have been somewhat decreasing. Pollution is concentrated in the area of Silesian Coal Basin, which, for example, produced 23 % of Poland's total SO_2 emissions in 1992, though it occupies only 2% of the country's area. Contribution of abandoned hard-coal mines processes in the Upper Silesian Coal Basin (USCB) to greenhouse gases pollution is discussed and a prognosis of future air pollution presented. During the last decades considerable improvements have been achieved in reducing air pollution in the country's industrial areas, usually as a result of the Government's efforts through legislative, regulatory and economic means. Also, monitoring of air quality has greatly improved during recent years. According to the Organisation for Economic Co-operation and Development (OECD) states report, between 1985 and 2004, the CO_2 emissions decreased in Poland by more than 30%, SO_2 by 40%, NOx by 4% and particulate matter (PM) by 44%. Potential future improvements in air cleaning with technology transfer and carbon dioxide sequestration is also discussed.

Key words: Greenhouse gas, Abandoned coal mines, Pollution, Upper Silesian Coal Basin.

INTRODUCTION

The Earth's atmosphere consists of a variety of gases, in that greenhouse gases transmitting solar and absorbing red wave length radiation. Absorption, taking place in the lower atmospheric strata, results in an increased temperature to finally lead to climatic changes (KOLENDA 2000). Some of these gases, chlorine compounds (CFC), also have a negative impact on the protective ozone stratum in the stratosphere, which adsorbs the ultraviolet radiation of the wave length $\lambda<2500$Å and protect the biological life on the Earth.

The presence of greenhouse gases in the troposphere (0 to 15 km over the surface of the Earth) reinforces the greenhouse effect 3500 to 7300 fold (18th World Gas Conference, Berlin, 1991) in a century's span of time. Nitrous oxides NOx (NO, NO_2) contribute to the growth of the ozone stratum in the troposphere, thus reinforces the greenhouse effect. An excess of ozone has a detrimental influence on the state of forests, vegetation and biocenosis in general. It may also cause a smog formation around urban areas.

The atmosphere also consists of volatile organic compounds (VOC), which together with nitrous oxides NOx significantly influence the growth of ozone O_3. Among the greenhouse gases are: water steam, ozone, carbon dioxide (CO_2), nitrogen oxide (N_2O), methane (CH_4), fluorohydrocarbons (HFC), carbon perfluorides (PFC-CF_4, C_2F_6, C_4H_{10}), sulphur and fluoride SF_6 compounds and aerosols (Institute of Environmental Protection, 2002). In the chlorine compounds (CFC) family, fluorochlorocarbons do not occur in nature; they are artefacts having highly negative impact on the greenhouse effect, which additionally destroy the stratigraphic ozone (15 to 50 km over the Earth's surface) – an ozone hole over the poles.

Two kinds of greenhouse effect can be distinguished: natural and anthropogenic. The influence of the latter one – a result of the man's activity, is still a subject to discussions and estimations (KOLENDA 2000). According to one of them (e.g. KOLENDA 2000), in 2000 the additional amount of energy received by the Earth as a consequence of anthropogenic effect was ca. 2.6 W/m^2 (annually, density of solar energy coming to the Earth is 236 W/m^2). The increasing share of greenhouse gases of anthropogenic origin over the last century is a known fact.

The strongest influence on greenhouse effect is exerted by the following gases: carbon dioxide, methane, ozone and CFC compounds (KARNOSKY & *al.* 2003). The share of these gases in reference to the 1980s is shown in Text-fig. 1 (18th World Gas Conference, Berlin 1991).

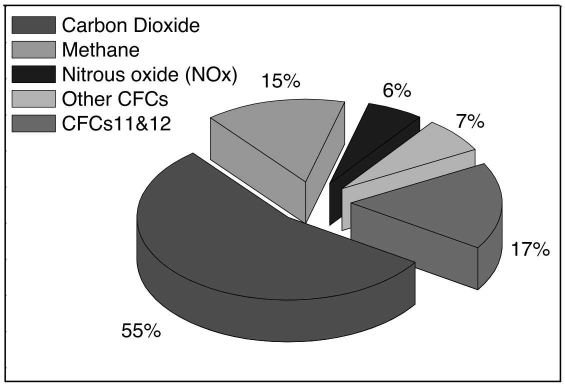

Fig. 1. Contributions of various gases to the total increase in climate forc ing during the 1980s (Institute Of Environmental Protection, 2002)

Greenhouse gases emission in Poland

In the past, Poland was a country having large (energy-consuming) heavy industry and power industry based on coal as a primary energy source. Since 1990 industry (heavy industry in particular) has been modernized and restructured. The contribution of hydrocarbons, mainly natural gas, to energy consumption has increased in the power industry and residential sector (KOLENDA & SIEMEK 1999, SIEMEK & *al.* 2003).

The share of primary energy sources in Poland in 2001 (in parantheses are data from 2004, according to Central Statistical Office Report for 2005) was the following: hard coal – 49% (45%), brown coal – 13% (14%), oil – 20% (24.5%), natural gas – 12% (12%), other (in that hydroenergy, biomass, wind energy, wood) – 6% (4.5%). The share of both types of coal is considerable, owing to the size of their deposits in Poland. Greenhouse gases emission values in 1988 to 2002 are presented in Table 1 (Institute of Environmental Protection, 2002, Warsaw).

By converting emitted gas weights to the equivalent MtCO$_2$[1] (million tone of CO$_2$), a so-called potential of global greenhouse effect for specific gases can be determined: 21 for CH_4 and 310 for N_2O in a century's span of time for example. The potential can be interpreted as a capability of gases to contribute to the greenhouse effect as equivalent to CO_2 contribution. Generally, the potential value for methane stays within range of 19 to 13. The magnitude of gas emissions in standard units (not converted to CO_2 equivalent) is presented in Table 2 (Institute of Environmental Protection, 2002, Warsaw).

In 2002 the global CO_2 emission decreased to 35.3% and CH_4 to 42.7% in reference to the year 1988. However, the N_2O emission increased by 3.6%. The methane concentration in the expelled gases was mainly caused by the

	Year									**Change in %**	
Gas	**1988**	**1990**	**1992**	**1994**	**1995**	**1996**	**1998**	**2000**	**2002**	**1998 base**[a]	**2000 base**[b]
CO_2	476.6	380.7	371.6	371.6	348.2	372.5	337.4	314.8	308.3	-35	-3
CH_4	66.0	58.8	52.0	51.8	51.6	47.3	49.0	45.9	37.8	-43	-3
N_2O	21.8	19.4	15.6	15.6	16.7	16.7	16.0	23.9	22.6	4	-5
HFCs*	NE	NE	NE	NE	0,02	0.07	0.22	0.89	1.26	6200	-2
PFCs*	NE	NE	NE	NE	0.82	0.77	0.81	0.72	0.27	-67	-69
SF_6*	NE	NE	NE	NE	0,00	0.00	0.01	0.02	0.02	737	0
Total	**564.4**	**458.9**	**439.2**	**439.0**	**417.34**	**437.34**	**403.44**	**386.23**	**370.25**	**-34.4**	**-3.2**

* 1995 is the base year for HFCs, PFCs and SF_6, NE – not estimated ; a - using formula ([2002]-[1988])/[1998]*100%, b - using formula ([2002]-[2000])/[2000]*100%

Table 1. National emissions of greenhouse gases for the years 1988-2002. [Mt CO_2 eq.]

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[1] 1 MtCO$_2$ = 10^6 ton of CO_2, Mg=10^6 g, Gg = 10^9 g, Tg= 10^{12} g

										Change in %	
Gas	**Unit**	**1988**	**1990**	**1992**	**1994**	**1995**	**1996**	**1998**	**2000**	**2002**	**1998 base^a**	**2000 base^b**
CO_2	Tg	476	380	371	371	348	373	334	315	308	-35	-3
CH_4	Gg	3141	2801	2474	2467	2457	2252	2335	2183	1800	-43	-3
N_2O	Gg	71	63	50	50	54	54	52	77	73	4	-5
HFC-23	Mg					NE	NE	NE	0.2	0.2	NE	0
HFC-32	Mg					NE	NE	NE	1.2	3.3	NE	65
HFC-125	Mg					NE	NE	NE	29.2	60	NE	28
HFC-134a	Mg					17	52	172	538	649	3652	-12
HFC-152a	Mg					NE	NE	NE	6.5	10	NE	33
HFC-143a	Mg					NE	NE	NE	27	62	NE	35
HFC-227ea	Mg					NE	0.1	0.2	0.8	1.2	NE	-68
CF4	Mg					111	104	108	94	36	-68	-67
C3F6	Mg					11	10	11	9.4	3.6	-68	-67
C4F10	Mg					0.0	0.6	0.9	3.3	0.0	NE	-100
SF6	Mg					0.1	0.1	0.2	0.7	0.8	700	14
Total	**Tg**	**564**	**459**	**439**	**439**	**417**	**437**	**403**	**386**	**370**	**-34**	**-3.2**

* 1995 is the base year for HFCs, PFCs and SF_6, NE – not estimated

a - using formula ([2002]-[1988])/[1998]*100% , b - using formula ([2002]-[2000])/[2000]*100%

Table 2. Total emission of greenhouse gases in 1988-2002 (INSTITUTE OF ENVIRONMENTAL PROTECTION, 2002)

decreasing number of coal mines and a drop of coal production. The methane emission was reduced by over 45%. In 2002 it was 0.568 Mt/year, i.e. ca. 793.1 106 m^3/year [*m^3 = normal cubic meter (0°C, 1 atm)], which makes ca. 31.6% of the total annual emission in Poland.

In 2002 Poland signed the UNU Framework Convention about Climate Changes (IPCC) in 1994 and the Protocol of the Climate Convention in Kyoto (1997). According to the Protocol, Poland shall reduce the greenhouse gases emission by 6% (CO_2 eq.) in the years 2008 to 2012 in reference to the quantities of 1988. The Government created a program which shall lay legal bases for emission market for SO_2 in 2005, for CO_2 in 2007 and for NOx in 2009 (Council of Ministers of Republic of Poland, 2002). Recently, the contingent for Polish CO_2 emission has been lowered. Percentage share of greenhouse gases emissions in Poland in 2002 is presented in Text-fig. 2.

The tabularized CO_2 emission value was reduced by the quantity absorbed by, e.g. forests and land which gives 257.57 Mt CO_2. The share of sectors producing CO_2 and CH_4 emissions in Poland in 2002 are presented in Text-figs 3 and 4, The industrial gases emission was evaluated on the basis of the IPCC Tier 2 and Tier 3 methods

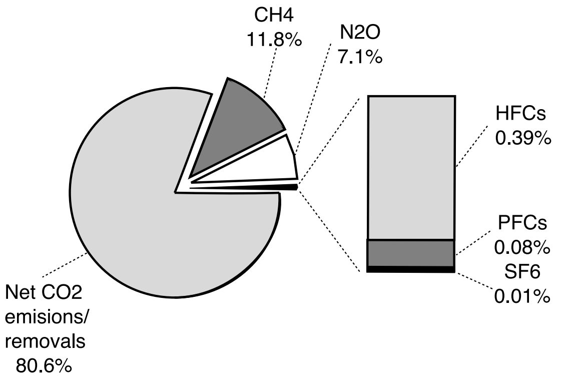

Fig. 2. Percentage share of greenhouse gases in total emission in Poland in 2002 (Institute of Environmental Protection, 2002)

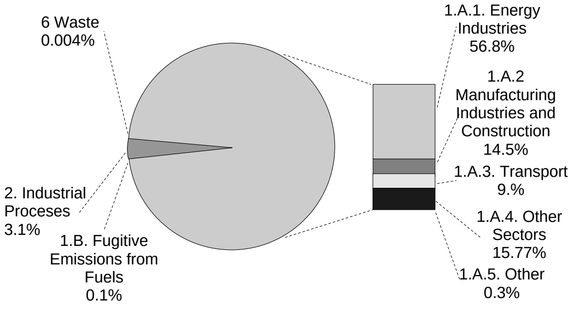

Fig. 3. Carbon dioxide emission produced by economy sector in 2002 (Institute of Environmental Protection, 2002)

(1996). The Tier 3 method is applied for assessing coal mine emissions (SCHEEHLE 2002). The following estimation formula is applied:

Emission = balance of underground gases (ventilation + degassing – use and consumption) + gas on surface + piles and instalments (underground and on surface).

Upper Silesian Coal Basin – methane emission

Coal beds in Poland are distributed in three coal basin: Upper Silesian Coal Basin (USCB - ca. 5800 km^2), Lower Silesian Coal Basin (LSCB) and Lublin Coal Basin (LCB) (Text-fig. 5).

Yet in the early 1990s four mines were operated in the LSCB, producing ca. 1.2 10^6 ton of coal. Now they are being closed and only nine in LCB is still carried out the production (ca. 22 10^6 ton). The remaining 130 10^6 tons of coal were produced by 65 mines in the USCB.

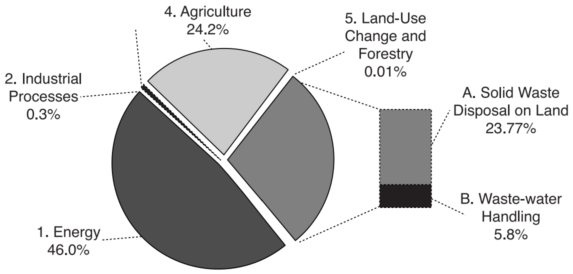

Fig. 4. Methane emission produced by economy sector in 2002 (Institute of Environmental Protection, 2002)

Year	No. of mines with methane-bearing seams	Share of coal production from methane-bearing seams, %		Absolute methane release rate (m^3/min)
		w/o methane extraction	With methane extraction	
1989	55	39	37	1989.6
1990	55	38	36	1881.5
1991	54	32	38	1577.7
1992	54	40	36	1613.6
1993	54	47	33	1483.9
1994	52	39	35	1431.0
1995	48	34	38	1418.0
1996	44	39	38	1400.2
1997	43	36	40	1504.7
1998	43	39	44	1453.6
1999	43	37	42	1436.1
2000	41	36	48	1470.0
2001	38	35	48	1440.2
2002	38	36	48	1455.6
2003	36	36	50	1522.5

Fig. 5. Location of coal basins, oil fields and gas fields in Poland

The characteristic of coal mining industry in 1989 to 2003 is presented in Table 3 (BRADECKI & DUBINSKI 2005).

The most abundant coal reserves are encountered in the USCB redundant. They cover about 87% of coal in Poland. The remaining 13% come from the LCB area. In 1979 the highest coal production in Poland reached 201 10^6 ton. The analysis of Table 3 prompts a conclusion that coal production is systematically decreased, which consequently results in a lower methane emission. The Upper Silesia covers an area of 12 294 km^2 and has 4.7 mln of population (13% of total population in Poland). This region abounds in city agglomerations sited on a distance of about 70 km. Apart from coal mines, there are 19 iron steel-mills, 9 power plants and 14 power and heat plants. Metallurgical industry is being restructured, and the LNM Holding (India) is the strategic investor. Bearing in mind the specific character of the region, methane emission is also accompanied by high CO_2 emissions (ca. 34 Mt/year). Fifty three plants are operational in the Upper Silesia area, each of them having CO_2 emissions over 50 10^3 T/year.

The analysis of CH_4 emissions caused by coal mines exploitation leads to conclusion that almost all the methane produced comes from the USCB. Small quantities of CH_4 may come from one coal mine in the LCB. The amount of methane in the abandoned coal mines in the USCB is assessed to range from 150 to 200 10^9 m^3, additional 200 10^9 m^3 are expected from the unexploited beds. Methane resources are associated with coal beds at depths from 700 to 1700 m (Polish Central Mining Institute, Katowice, 2004). The typical coal-bed methane concentrations range from 0.2 to 23 m^3/t, (US Environmental Protection Agency, 1995). This would correspond to concentration of ca. 200 10^6 m^3/km^2. CH_4 concentration was determined by two different methods, producing somewhat different results. Difference lies in the way of coal core sampling methods (US Epa, 2001, 1995)

Indicator	Years			
	1989	1995	2000	2003
Coal production (millions of tones)	177.4	135.4	102.2	99.7
Export (millions of tones)	28.9	32.3	23.0	20.0
Recoverable reserves (billions of tones)	30.7	25.2	18.1	15.9*
Developed reserves	12.8	9.2	5.8	5.1*
Number of mines	70	63	42	41

* as of 31.12.2002

Table 3. Hard coal mining indicators (years 1989-2003) (BRADECKI & DUBINSKI, 2005)

Poland is leading producer, so it also leads in coal-bed methane emissions. In 1993, 4% of the world methane emissions were from the USCB area. Also, the coal-bed methane emissions in 2002 amounted to about 793.1 10^6 m^3/year[i]. The emitted stream comprises of methane from coal-bed gas coal degassing, mine ventilation systems, diffusion release from mines, piles, storages and mine's installations, as computed with the Tier 2 and Tier 3 methods (Institute of Environmental Protection, 2002).

By comparison to the 2002 data, the emissions in 1988 were about 1391.1 10^6 m^3/year for the whole Polish coal mining and 1349.4 10^6 m^3/year for USCB. Literature and reports of environmental agencies quote various data on CH_4 emission in the USCB. For instance, the report of the in US Environmental Protection Agency, gives the following data concerning emissions from 32 "gassed" coal mines in the USCB:

Year	1988	1989	1993	1996	2003
CH_4 (10^6 m^3/year)	1349	1045.7	779.0	735.8	799.9

Table 4. Production methane in mines (Bradecki &Dubinski 2005)

Year	No. of mines with methane-bearing seams	Share of coal production from methane-bearing seams, %		Absolute methane release rate (m^3/min)
		w/o methane extraction	With methane extraction	
1989	55	39	37	1989.6
1990	55	38	36	1881.5
1991	54	32	38	1577.7
1992	54	40	36	1613.6
1993	54	47	33	1483.9
1994	52	39	35	1431.0
1995	48	34	38	1418.0
1996	44	39	38	1400.2
1997	43	36	40	1504.7
1998	43	39	44	1453.6
1999	43	37	42	1436.1
2000	41	36	48	1470.0
2001	38	35	48	1440.2
2002	38	36	48	1455.6
2003	36	36	50	1522.5

Table 5. Gas hazards in coal mines in the years 1989 to 2003 (Bradecki & Dubinski 2005)

1. Methane from drainage operations	212.8 10^6 m^3/year
2. Methane from ventilation air	540.7 10^6 m^3/year
3. Utilised methane	167.7 10^6 m^3/year
4. Methane emitted directly to the atmosphere	585.8 10^6 m^3/year

Methane released from the surface, mines and mining areas has not been accounted for in this report. Other information about methane in exploited mines are also available in Bradecki & Dubinski (2005) (see Table 4):

The variability of methane production in mines is presented in Table 5 (Bradecki & Dubinski 2005).

The following conclusions can be inferred from Table 5:

(i). The methane release rate reduced over time due to a reduced number of "gassed" coal mines;

(ii) The share of coal produced from "gassed" mines remains constant - about. 37% while the coal in 1989 - 2003 time period reduced by almost 45%. This can be due to the increase of gas hazard in mining industry;

(iii) The coal production in mines equipped with degassing systems, is by 50% of total coal production.

According to U.S. Environmental Protection Agency (2001), the methane emission associated with coal production should be significantly reduced (Table 6):

For comparison, analysis of methane emissions in Poland, reduces data considerably to that by USA EPA. This may result from various methods used for the assessment estimation rather than the hard numbers, as shown in the Table 7. Thus, it seems most appropriate to give range for specific spans of time (Table 7):

Year	Extrapolation 1990	1995	2000	2010
CH_4 (10^9 m^3/year)	1.116	1.036	0.983	0.890

Table 6. Methane emission related with coal production (U.S. Environmental Protection Agency, 2001)

Year	1988 -1990	1993	1995	2000	2002
CH_4 (10^6 m^3/year)	998-1391.1	585.8-779.9	745.3-1036	772.2-983	764.7-793.1

Table 7. Methane gases emission in Polish mining from1988 to 2002 (authors' estimations)

Statistics from the Institute of Environmental Protection, published in official Polish reports, has been a base for our considerations. Relative error of these statistics is equal to about 14%.

In the year 2004 and in the beginning of the year 2005, 40 and 39 coal mines, respectively, were operational in the USCB. 34 of them were classified as "gassed" (Gatnar & Skiba 2003), and 36 as exploiting seams with methane (Bradecki & Dubinski 2005). Draining systems were installed in 23 mines; 17 of them had surface instalments for methane-removal, and in 15 mines methane was used as an energy source.

Potential use of coal-bed (CBM) methane and coal mine methane (CMM) in the Upper Silesian Coal Basin

World's coal mining industry is responsible for methane emissions totaling to 22 10^{12} g/year, which makes 12% of gaseous pollutions (Warmuzinski & *al.* 2003). Poland emits about 0.600 10^{12} g/year, i.e. 2.7% of global coal-bed methane emission.

Coal-bed methane is drained through special systems of degasification wells, or pipelines installed in the gob and removed from the mines with ventilation air. According to data for the year 2004 (Gatnar & Skiba 2003), methane draining systems installed in the USCB mines produced 250.88 10^6 m^3 CH_4/year, at a rate of 481.11 m^3/min. Out of this quantity, 144.82 10^6 m^3/year (ca. 57%) was utilized, and 106.05 10^6 m^3/year was lost, i.e. emitted to the atmosphere.

Two draining technologies are applied: pre-exploitation, preparation technology, and the other, more efficient one, i.e. drainage in the immediate vicinity of the coal faces (longwalls). The second technology enables intaking of 20 to 30% of methane emitted in the course of active longwall exploitation works, 25 to 50% of methane through boreholes preceding the longwall extraction area, 40 to 60% of methane at longwalls with

Considerations	Enhanced Gob Well Recovery	Pre-Mining Degasification	Ventilation Air Utilization	Integrated Recovery *Combined strategies*
Recovery Techniques	In-Mine Boreholes Vertical Gob Wells	Vertical Wells In-Mine Boreholes	Fans	All Techniques
Support Technologies	In-Mine Drills and/for Basic Surface Rigs Compressors, Pumps, and other support facilities	In-Mine Drills and/for Advanced Surface Rigs Compressors, Pumps, and other support facilities	Surface Fans and Ducting	All Techniques Ability to Optimize Degasification using Combined Strategies
Gas Quality	Medium Quality (11-29 MJ/m^3) (300-800 Btu/cf) (approx. 30-80% CH_4)	High Quality (32-37 MJ/m^3) (900-1000 Btu/cf) (above 90% CH_4)	Low Quality (<1% CH_4; usually below 0,5%)	All Qualities
Use Options	On-Site Power generation Gas Distribution Systems Industrial Use Cogeneration systems Refrigeration and Air Condition	Chemical Feedstocks *in addition to those uses listed for medium quality gas*	Combustion Air for On-Site / Nearby Turbines and Boilers	All Uses
Availability	Currently Available	Currently Available	Requires Demonstration	Currently Available
Capital Requirements	Low/Medium	Medium/High	Low/Medium	Medium/High
Technical Complexity	Low/Medium	Medium/High	Medium/High	High
Applicability	Widely Applicable Site Dependent	Technology, Finance, and Site Dependent	Nearby Utilization Site Dependent	Technology, Finance, and Site Dependent
Methane Reduction*	Up to 50%	Up to 70%	10-90% recovery	80-90% recovery

* These reductions are achievable at specific sites of systems

Table 8. Summary of options for reducing methane emission from coal mining (U.S.EPA, 1993)

double ventilation galleries, and finally 50 to 76% of CH_4 from gobs cavings and galleries over the longwalls. The methane concentration in the drained gas reaches (GATNAR & SKIBA 2003):

(i) Ca. 90% from boreholes drilled from the surface;

(ii) 30 to 70% from underground drainage through boreholes in the vicinity of the extraction area;

(iii) 20 to 90% from drainage of gobs and spaces closed by dams, by pipelines;

(iv) 60 to 95% from drainage through large-diameter boreholes drilled through the exploited longwalls or gobs.

Gas coming from draining operations is utilized only in some of the USCD mines. It is mainly used for:

(i) Combustion in coal driers' burners (post-flotation processes);

(ii) Hot water boilers for the needs of mines and neighborhoods;

(iii) Heat and electricity production in co-generation systems, distribution to other mines and housing estates;

(iv) Power and refrigeration systems, air-conditioning stations, transport to gas distribution networks.

Air from mine's ventilation systems contains from 0.1 to 1 vol. % of methane (maximum 1.5 vol. %). The most frequent methane concentration is below 0.5%. Fugitive methane emitted with ventilation air can be utilized as follows (WARMUZINSKI & *al*. 2003):

(i) Increasing methane concentration by the variable pressure adsorption method. It is possible to obtain ca. 90% methane concentration and 30% to 50% of effectiveness;

(ii) catalytic methane removal from ventilation air in a flow reverse reactor with simultaneous water steam production in the exothermal part of the reactor (ca. 723°K);

(iii) transport of ventilation air to coal-boilers. In Poland, one ventilation shaft produces air from 270 10^3 to over 1 10^6 m^3/h. It contains 0.3% of methane. This utilization method would be economically justified if the distances between the customer and the source of supply were from 3.5 to 4 km (maximum to 6 km).

The above solutions are interesting and potentially applicable in the future. A review of coal-bed methane application methods is presented in Table 8 (U.S. Environmental Protection Agency, 1995).

The USCB has a great, still unused potential as far as coal-bed methane recovery and management are concerned. The methane resources are bigger than natural gas resources. A wider use of methane would considerably improve the quality of air in the Upper Silesia. Methane combustion produces less CO_2 than coal combustion. Besides no sulphur compounds (present in coal) are emitted to the atmosphere and the methane content in the atmospheric air is lower. The basic application of methane is for local purposes (only then through the distribution network). The option selection depends on the quality of gas, its calorific value, applied management method, continuity of delivery, drainage systems, methane resources, cost of management and economic analysis of the return rate.

In the years 1990 to 1996 a few foreign companies were interested in exploiting coal-bed methane in Poland, e.g. Amoco, Texaco, McCormick, Metanel-Poland (SIEMEK & *al.* 1994). The technology of boreholes drilled from the surface to the coal beds was tested. However, exploration and technical works have been stopped.

One of the methods of reducing CO_2 content is its injection to the porous strata in depleted hydrocarbon beds, and into the coal beds (the so-called coal sequestration). CO_2 sequestration in coal beds may be also connected with methane enhanced production (CO_2 exerts CH_4 adsorbed in coal). An international project EU "Recopol" is going in Poland now. The main element of the project is observation of the results of injecting liquid CO_2 through the borehole to a coal bed at about 1120 m of depth and control of CH_4 and CO_2 concentrations in the observation borehole, 150 m from the injection well (PAINIER 2003)

The project is financed by the European Union, with the Central Mining Institute in Katowice, Poland, as the main coordinator.

Another way for managing mines under closing is to convert them into underground gas storages (Polish Central Mining Institute, Katowice 2004).

CONCLUSIONS

The paper proves the following theses:

(i) Due to the restructuring of coal mining industry in Poland, in the years 1989 to 2003 the quantity of methane emitted by mines was reduced by 45%. Almost 30% of reduction was in the years 1989 to 1996, when 11 "gassed" mines were closed;

(ii) Despite considerable methane reserves in the Polish coal beds, its production and utilization are on a very low level, not corresponding to the possibilities. In the future projects of methane exploitation are expected to be more readily undertaken. Owing to the civic character of the Upper Silesia, dense space development and a great number of industrial objects, coal-bed methane management and distribution will most probably be technically easier and more economic. Conversion of selected workings into underground gas storages would certainly improve the exploitability of coal-bed methane;

(iii) Coal-bed methane, similar to coal, could be a significant energy safety element in Polish economy;

(iv) Poland prepares a coherent legal systems enabling SO_2, CO_2 and NOx emissions trading in relation to the European law;

(v) The Upper Silesia region, being a center of the Polish coal mining industry, is strongly endangered with greenhouse gases emissions. The 42% reduction of coal-bed methane emissions had a positive influence on the quality of air in that area;

(vi) The quantity of methane coming from mine's draining operations and its utilization vary to a small degree. The quantity of the gas utilized for local purposes can be at least doubled;

(vii) Some discrepancies in coal-bed methane emission data in the USCB are observed. They can be as much as 30% for the years 1988 to 2000. They are due to differences in the calculation methods and classification of emission components;

(viii) Estimated lowering of emissions stays within an interval of 12 to 45%; sometimes reports give 26.8%,

(ix) Total CO_2 and CH_4 Emission for Poland in the period 1988 to 2002 lowered by 35% and 43%, respectively. After reaching its minimum in the years 1992 to 1994 (restructuring of Polish industry), N_2O emission stays on a similar level.

Owing to the predicted drop of coal production, further decrease in methane emission is expected. However, a significant increase in methane extraction and management are possible.

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