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Inventory of methane emissions from ventilation and degasification systems of hard coal mines in Poland in the years 2001-2010

Abstract

On the basis of literature review concerning methane emission in Poland, it was stated that in 2009 National Greenhouse Inventory 2007[1] was published. It was prepared firstly to meet Poland's obligations resulting from point 3.1 Decision no. 280/2004/WE of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol, and secondly for the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol.

The *National Greenhouse Inventory* states there are no detailed data concerning methane emission in collieries in Polish mining industry. That is why methane emission in methane coal mines of Górnośląskie Zagłębie Węglowe – GZW (Upper Silesian Coal Basin - USCB) in Poland was studied and meticulously calculated. The applied methodology for estimating methane emission from GZW coal mining system was used for the two basic sources of its emission. Methane emission during the mining process as ventilation emission and drainage systems emission. Such an approach resulted from IPCC[2] guidelines of 2006.

Updating the proposed methods (IPCC 2006) of estimating methane emission from ventilation systems and degasification systems of hard coal mines (active ones and abandoned ones) in Poland assume that methane emission factor (EF) is calculated on the basis of methane coal mine output and actual values of absolute methane content. The result of modification the method of estimating methane emission during the mining process for Polish coal mines is the equation of methane emission factor EF.

1. Introduction

On the basis of statistics conducted at the Central Mining Institute (GIG Poland) in the form of the "*Annual Report (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry*"[3], in the chapter concerning the *Gas hazard*, It was specified the data on hard coal output, absolute methane emissions, methane drainage and methane management from mines in the Upper Silesian Coal Basin in the years 2001-2010. In every of the analysed years it was possible to separate output quantities from mines classified as CMM mines. It has been estimated on this basis the number and output of mines defined as CMM mines. In conformity with the *Annual Report* …, methane and connected with it explosion hazard is one of the most dangerous phenomena accompanying hard coal production in the Polish mining industry.

[1] National inventory of greenhouse gas emissions and absorption for 2007. Report prepared for the needs of the United Nations Framework Convention on Climate Change and Kyoto Protocol. NATIONAL ADMINISTRATOR OF THE EMISSIONS TRADING SCHEME. NATIONAL EMISSIONS INVENTORY CENTRE. Institute of Environmental Protection. Warsaw, May 2009.
[2] IPCC (2006). Guidelines for National Greenhouse Gas Inventories.
[3] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011

The classification of coal seams in Polish mines according to the appropriate methane hazard category is determined by the Order of the Minister of Internal Affairs and Administration of 14 June 2002 on natural hazards in mines. (Journal of Laws of the Republic of Poland of 1 July 2002, item 841 along with the amendment introduced by the Order of the Minister of Internal Affairs and Administration changing the order on natural hazards in mines (with respect to the methane hazard the changes concern the article 12, section one)) (*Order …*[4] 2002).

Generally, the areas of methane emissions in the mine can be systematised due to the level and dynamics of methane emissions in the following order: winning operations, gobs, development operations, active roadway excavations (Konopko[5] 2010).

In the years 2001-2010 exploitation of coal seams in Poland was conducted in mines specified in *Annual Report*[6]). In 2001 Mining operations in CMM seams were conducted in 29 mines. The total output was estimated to 102.78 million tons, including 72.37 million tons from CMM seams. From the 43 of the operating mines 30 were CMM mines. Data in the *Annual Report…* indicate 2 mines to be closed and one of them was a CMM mine. In the 2002 hard coal production in Poland was amounted to 102.07 million tons, including 72.13 million tons from CMM mines. According to the all collected data the number of CMM mines was the same. The methane emissions has been recorded in one of the closed mines (similarly as in the previous year – the Niwka-Modrzejów colliery). In 2003 the output was similar and reached the level of 100 million tons, and the output decrease from CMM seams to the 65.71 million tons. In this year hard coal production concerned 41 mines, including 29 mines classified among CMM mines. In 2004 the output from 41 mines decreased to 99.17 million tons, while the output from 29 CMM mines compared to the previous year increased to 67.71 million tons. In this year 1 mine has been closed and the existing mines Rydułtowy and Anna were joined. In the year 2005 the output decreased in total to 97.17 million tons, and therefore the decrease of output from CMM seams estimated to 67.35 million tons. Generally in this year methane was recorded from 24 mines and some mines were joined, so the number of mines dropped to 35. In 2006 from 31 operating mines obtained 94.27 million tons of coal, including 64.52 million tons from 24 CMM mines. The year 2007 was a year of a downward tendency in a output of coal. Same as in the previous year, from 31 mines 87.40 million tons of hard coal were obtained. The coal production decrease caused the decrease of an output from the CMM mines, which amounted to 62.47 million tons. In 2008 recorded an output on the level of 83.40 million tons. From 29 operating mines 23 mines were declared as the CMM mines, and their output estimated to 57.54 million tons. 30 mines were operating in the year 2009, its result was an output on the level of 77.27 million tons. From 23 mines classified as CMM ones obtained 53.27 million tons of coal. In that year occured another join of two mines (Staszic colliery and Murcki colliery). In the 2010 the last analysed year, the output from 29 mines estimated to 76.15 million tons. From 21 CMM mines in 2010 52.18 million tons of hard coal were obtained. The decrease of the number of existing mines, similarly as in the preceding year, concerned the subsequent joining of two from among operating mines – Knurów colliery and Szczygłowice colliery.

[4] Order of the Minister of Internal Affairs and Administration of 14 June 2002 on natural hazards in mines (Journal of Laws of the Republic of Poland of 1 July 2002, item 841 along with the amendment introduced by the Order of the Minister of Internal Affairs and Administration changing the order on natural hazards in mines (with respect to methane hazard the changes concern the article 12, section 1)).
[5] Conditions of safe exploitation of coal seams threatened by methane, rockbursts and fires. Collective work edited by Władysław Konopko. Publ. GIG, Katowice 2010
[6] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011

Summarizing the above-mentioned facts it should be stated that in the years 2001-2010 the number of operating hard coal mines in Poland was reduced from 43 in 2001 to 29 in 2010, thus the output decreased from 102.78 million tons to 76.15 million tons. The reduction in the number of mines, consisting particularly in joining of neighbouring mines, also influenced the decrease of the number and output from CMM mines. In the year 2001 30 CMM mines have produced 72.37 million tons, and in the year 2010 barely 21 mines have produced 52.18 million tons of coal.

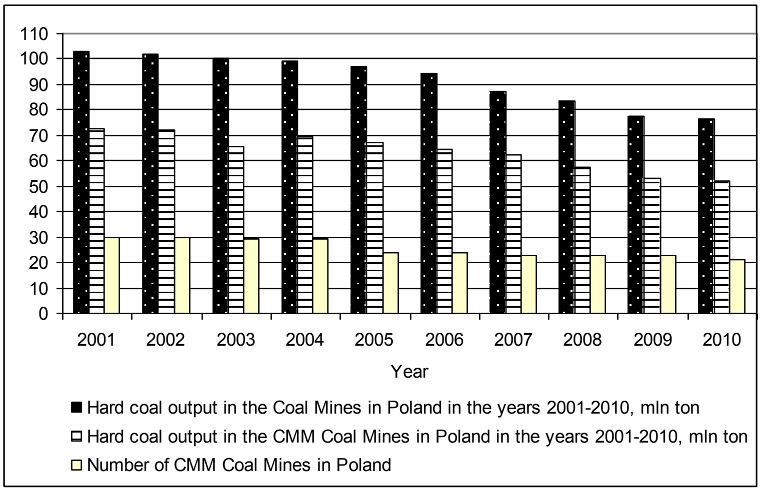

Fig. 1.1. Production of hard coal in CMM coal mines against the background of the number of CMM mines in the years 2001-2010

Polish hard coal deposits, especially in the central, southern and south-western part of the Upper Silesian Coal Basin, belong to deposits with high methane content (*Annual Report*..[7] 2002-2011). The Carboniferous deposits are covered by an overburden of non-permeable Tertiary and Quaternary layers of great thickness, what caused that methane remained in coal seams. The saturation of high methane creates a hazard while conducting of mining operations. Methane emissions from Polish hard coal mines concern:

- areas of mined longwalls, i.e. they originate from the mined seam as well as from underworked and overworked seams decompressed in consequence of longwall mining. Methane from underworked and overworked seams is emitted to post-mining gobs;
- post-mining gobs – isolated from active mine excavations by explosion-proof dams in the neighbourhood of isolation dams and fractures in the rock mass, through which methane is emitted into the excavations. Methane from post-mining gobs in some mines is captured by the method of methane drainage;
- drilled development excavations.

Methane from the seam were both development and winning operations are conducted, migrates into the mine atmosphere. From these seams methane cannot be captured using the method of methane drainage. Only 3% of the total amount of methane captured by means of

[7] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011

methane drainage originate from advancing methane drainage conducted in driven roadway excavations.

Generally advancing methane drainage in Polish hard coal mines below the depth of 400 m is characterised by low capture effectiveness. The gas permeability of seams in the Upper Silesian Coal Basin is very low, what renders difficult methane flow in the coal matrix of the seam, in which mining operations are conducted. As an example can be mentioned the conditions existing in mines in the United States of America or Australia, where coals have permeability about 50 times higher than coals in the Upper Silesian Coal Basin. In these countries pre-mining methane drainage, even by means of boreholes drilled from the surface, is conducted.

Methane capturing from seams in the Upper Silesian Coal Basin, in which exploitation is planned causes that during exploitation we deal with a seam of considerably lower methane saturation, than primarily.

Along with exploitation ending do not terminate methane emissions into excavations from decompressed underworked and overworked seams. The model of methane emissions from longwall gobs, after exploitation ending, was inserted in the Instruction GIG[8] No 14/2000. The value of methane emissions into the excavations of an abandoned mine depends:

- on the average weighted methane content of the mined out deposit,
- on the volume of decompressed overworked and underworked seams,
- on the time of abandoned mine flooding,
- on the height of the column of water above underworked and overworked seams.

As it results from statistics conducted in the *Annual Report*...[9] (2001-2011), in the Polish coal mining industry in the years 2001-2002 methane emissions were noted from one abandoned mine: Niwka-Modrzejów colliery.

In spite of considerable progress in the recognition and fighting of the methane hazard, in Poland its growth in many mining areas of mines in the Upper Silesian Coal Basin is observed. This is connected with the growth of depth of conducted exploitation, higher and higher methane content of seams and gas deposit pressure.

Exploitation on greater and greater depth, in seams highly saturated with methane, has caused cumulation of the quantity of emitted methane in a smaller number of longwall workings, and thus the growth of their absolute methane emissions.

The statistics of mining catastrophes caused by methane or methane and coal dust explosions in the history of the Polish underground mining sector is the most tragic one, both on account of the number of fatalities and serious accidents as well as caused material damages (Kidybiński, Patyńska[10] 2008).

Methane causes also negative ecological effects in the case, when it is carried away directly with the ventilation air to the atmosphere. Simultaneously it is an ecological energy fuel with a high calorific content.

The investigations into occurred methane explosions contributed to the development of methods and means of recognition and prediction of the methane hazard, extension of control of the methane content in the air of excavations as well as development of means and methods of

[8] Dynamic prediction of longwall absolute methane emissions (technical hand-book). Instruction of GIG No 14, Katowice 2000
[9] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
[10] Kidybiński A, Patyńska R.: *Analysis of gas-geodynamic phenomena in hard coal mines in Poland and in the world.* MONOGRAPH. Scientific Works of GIG, Katowice 2008, reviewed by Prof. Marian Kolarczyk. Pages 1-110

its combating, including methane drainage. Correct recognition of the methane hazard state and its efficient fighting have basic significance in conducting safe exploitation (Patyńska[11] 2010).

Taking the above-mentioned factors into consideration, at the Central Mining Institute yearly is elaborated a report about the state of the methane hazard in the Polish mining industry. Using the data presented in the present *Annual Report*...[12](2002-2011), below in Table 1.1 data related to the output and quantity of emitted methane from individual mines have been specified. As it results from the statistics conducted in the *Annual Report*..., in the years 2001-2010 in the Polish coal mining industry 1 mine was closed, namely the Niwka-Modrzejów colliery; in spite of this fact measurements of methane emissions were performed till the year 2002. The results of measurements from the years 2001-2002 were taken into consideration in annual calculations and specifications of the estimated ventilation emissions.

The data specified in Table 1.1 and in allow to state that in spite of coal production drop and decreasing number of mines in the Upper Silesian Coal Basin in Poland, methane emissions from coal exploitation processes in CMM mines since 2001 increased by about 50 m^3/ton in 2010.With the passage of time, the efforts regarding methane drainage brought positive effects. Every year grows the quantity of methane captured by methane drainage systems and the quantity of utilized methane.

Table 1.1. Collecting and organization of data on methane emission in hard coal mines (active and abandoned) in Poland from last 10 years (2001-2010)

Year	Number of CMM Coal Mines in Poland	Hard coal output in the CMM Coal Mines in Poland, milion t	Relative methane emissions from active Coal Mines in Poland - Mining - Ventilation methane emission (VAM), m^3/tonne	Relative methane emissions from degassing systems, m^3/tonne	Relative methane emissions - loss emissions, m^3/tonne	Absolute methane emissions from abandoned mines (AMM) in Poland, milion m^3/year
2001	30	72.37	300.22	82.74	30.71	0.91
2002	30	72.13	304.08	78.11	30.91	0.73
2003	29	65.71	345.69	92.08	40.57	-
2004	29	69.17	320.26	91.14	38.41	-
2005	24	67.35	287.98	87.57	37.23	-
2006	24	64.52	305.62	NA	NA	-
2007	23	62.47	325.56	101.33	38.20	-
2008	23	57.54	361.11	116.40	51.15	-
2009	23	53.27	385.35	120.09	43.18	-
2010	21	52.18	350.78	110.82	38.58	-

[11] Patyńska R.: Rock mass structure and its influence on gas parameters of deposits in which coal outburst and squealer hazard occur. III Traditional International Colloquium on Geomechanics and Geophysics, Ostavice 06-07.05.2010r., Czech Republic, pages 207-225. Publishers: Akademie vêd České republiky, Ústav Geoniky, v.v.i. (Academy of Science of the Czech Republic, Institute of Geonics), Ostrava 2010

[12] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011

2. Methane emissions inventory in mines in the Upper Silesian Coal Basin in Poland

In Poland in 2009 the National Inventory Report on Greenhouse Gas Emissions and Absorption for 2007[13] (2009) was published, prepared in order to fulfil the obligations of Poland, in conformity with the requirements of article 3.1 of the decision No 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol, as well as for the needs of the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol. The basic intention of this protocol is the reduction of greenhouse gas emissions by at least 5% below the level of 1990 in the period of obligations 2008-2012 by countries mentioned in Annex 1 to the United Nations Framework Convention on Climate Change (UNFCCC).

The key proof regarding the fulfilment of obligations in relation to the convention and its protocol is the yearly elaboration of greenhouse gas emission and absorption inventory by the parties of the convention. The information comprised in the report (National Inventory...2009) were prepared in accordance with the updated guidelines (decision 14/CP.11): „Guidelines for the Preparation of National Communications by Parties included in Annex I to the Convention, Part I: UNFCCC Reporting Guidelines on Annual Inventories" (included in the document FCCC/SBSTA/2006/9). The report has been also supplemented by additional information in conformity with the requirements of article 7.1 of the Kyoto Protocol and determined recommendations in the decision 15/CMP.1.

The report of the National Emissions Inventory Centre (KCIE) is the equivalent of the English National Inventory Report (NIR) and presents the results of national inventory of greenhouse gas emissions and absorption in Poland in 2007. The inventory has comprised greenhouse gases, including methane – CH_4.

The national inventory and accompanying it tables in the system Common Reporting Format (CRF) has been prepared in accordance with the updated guidelines *UNFCCC Reporting Guidelines on Annual Inventories* (FCCC/SBSTA/2006/9). The guidelines for the calculation of emissions and absorption of greenhouse gases are consistent with the methods recommended in basic publications of the Intergovernmental Panel on Climate Change – IPCC, a namely *Revised 1996 Guidelines for National Greenhouse Gas Inventories* and *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*. In conformity with the IPCC[14] (2006) guidelines being in force, in order to obtain more accurate data about emissions there where it was possible, national methods of emission estimation were used.

The preparation of the national inventory of greenhouse gas emissions and absorption as well as other air pollutions for the needs of the United Nations Framework Convention on Climate Change (UNFCCC) and Convention on Long-Range Transboundary Air Pollution (CLRTAP), belongs in Poland to the tasks of the National Emissions Inventory Centre (KCIE) established in the year 2000 at the Institute of Environmental Protection in Warsaw. Since 2006 the Centre realises its tasks in the framework of the National Administration of the Emissions Trading Scheme

[13] National inventory of greenhouse gas emissions and absorption for 2007. Report prepared for the needs of the United Nations Framework Convention on Climate Change and Kyoto Protocol. NATIONAL ADMINISTRATOR OF THE EMISSIONS TRADING SCHEME. NATIONAL EMISSIONS INVENTORY CENTRE. Institute of Environmental Protection. Warsaw, May 2009.
[14] IPCC (2006). Guidelines for National Greenhouse Gas Inventories

(KASHUE[15]) established also at the Institute of Environmental Protection on the basis of the *Order of the Minister of Environment of 13 September 2005 on the appointment of the National Administrator of the Emissions Trading Scheme.* The tasks of the National Emissions Inventory Centre (KCIE) comprising the calculation and notification of greenhouse gas emissions inventory were determined in the agreement signed between the Institute of Environmental Protection, Ministry of Environment and the National Fund of Environmental Protection and Water Management (NFOŚiGW) in 2000 an extended in an analogical agreement of 2006 between the National Administrator of the Emissions Trading Scheme/Institute of Environmental Protection, National Fund of Environmental Protection and Water Management and the Ministry of Environment.

The works regarding the inventory of greenhouse gas emissions, including emission calculation, selection and development of the methodology, selection of activity and emission factor are realized in the National Emissions Inventory Centre (KCIE).

In the preparation of the inventory the Centre KCIE cooperates with individual experts, and also institutions, to which belong: the Central Statistical Office of Poland (GUS), Energy Market Agency (ARE SA), Institute for Ecology of Industrial Areas (IETU), Motor Transport Institute (ITS), Bureau of Forest Management and Geodesy (BULiGL). The above-mentioned institutions are involved first of all in the process of delivery of data about activities. The team of National Emissions Inventory Centre (KCIE), being a unit in the National Administrator (KASHUE), has access to data submitted through enterprises participating in the European Union Emissions Trading Scheme (EU-ETS). This ensures access to data about emissions from stationary sources (1.A.1, 1.A.2), as well as from selected industrial processes. These data, after verification, are successively included into the national inventory of greenhouse gas emissions (National inventory...[16] 2009).

The inventory of greenhouse gas emissions and absorption is performed on the basis of currently being in force IPCC guidelines, and in the case of greenhouse gas precursors in conformity with the methodology developed by UN ECE/EMEP (IPCC[17] 1997, IPCC[18] 2000, EEA 2004). There, where it was possible, national factors and inventory methodology have been elaborated.

The currently applied methodology of estimation of greenhouse gas emissions is consistent with the being in force guidelines prepared by the Intergovernmental Panel on Climate Change (IPCC 1997, IPCC 2000). Here have been used also national methods of emission estimation consistent with the newest IPCC guidelines (2006) for the reflection of the specificity of Polish conditions.

The methodology, emission factors, data about activities and measurements applied in the Polish inventory till the year 2007 have been described in chapters 3-8 of the Report of the National Emissions Inventory Centre (KCIE)[19].

The emission sources in all categories are identified as *main emission sources* on the basis of their share in national emissions and/or assessment of emission trend in conformity with the

[15] KASHUE (2009). Database of the National Administrator of the Emissions Trading Scheme, containing information about installations covered by the emissions trading scheme along with data originating from verified reports about the annual CO_2 emissions. Institute of Environmental Protection. Warsaw

[16] National inventory of greenhouse gas emissions and absorption for 2007. Report prepared for the needs of the United Nations Framework Convention on Climate Change and Kyoto Protocol. NATIONAL ADMINISTRATOR OF THE EMISSIONS TRADING SCHEME. NATIONAL EMISSIONS INVENTORY CENTRE. Institute of Environmental Protection. Warsaw, May 2009

[17] IPCC (1997). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Reference Manual

[18] IPCC (2000). Good Practice Guidance and Uncertainty Management in National GHG Inventories

[19] National inventory of greenhouse gas emissions and absorption for 2007. Report prepared for the needs of the United Nations Framework Convention on Climate Change and Kyoto Protocol. NATIONAL ADMINISTRATOR OF THE EMISSIONS TRADING SCHEME. NATIONAL EMISSIONS INVENTORY CENTRE. Institute of Environmental Protection. Warsaw, May 2009

methodology [IPCC[20] 2000]. Full tables prepared in conformity with the guidelines (IPCC 2000), including the assessment of emission level and assessment of the trend were presented in Annex 1 (KCIE).

The report of the National Emissions Inventory Centre (KCIE) gives in the Tables 2.2 and 2.3 that methane emissions in Poland in 2007 for Solid Fuels, including hard coal, amount to 410.05 Gg, what constitutes 23.77% of share in individual categories in the national CH_4 emissions.

Methane emissions (without category 5) in 2007 amounted to 1 725.01 Gg, i.e. 36.23 million tons of CO_2 equivalent. The share of methane in the total national greenhouse gas emissions in 2007 amounted to 9.1%. The emissions of the first of mentioned categories comprise among other thinks emissions from *Underground Mines* (about 23.8% of total CH_4 emissions).

Using the results of two methodological works (Gawlik et al.[21], 1994 and Gawlik and Grzybek (G&G)[22], 2001) national emission factors for the following emission sources in hard coal mines were determined (PIG[23] 2008):

- from ventilation systems
- from methane drainage systems
- from mined out coal from post-exploitation (post-extraction) processes.

For the year 1999 annual emissions from an abandoned mine were estimated, what allowed to estimate the emission factor with reference to this emission source.

In the table below have been presented the hitherto used in national emissions inventories emission factors for individual emission types. Also the results from the work (Kwarciński et al.[24], 2005), were specified in the table, in which have been estimated – once again – the emission factors on the basis of very detailed data and measurements for the year 2003; furthermore, a thorough analysis of emission factors was carried out, comparing them with the results of previous works. For the needs of the national inventory the emission factors per ton of mined coal were calculated – these values are generally available, for example from the publication of the State Geological Institute[25] (PIG, 2008) (Table 2.2).

[20] IPCC (2000). Good Practice Guidance and Uncertainty Management in National GHG Inventories.
[21] Gawlik L. et al. (1994). Determination of greenhouse gas emission sources connected with the exploitation of the coal system (hard and brown coal) along with the determination of emission factors in sources of the emission system, calculation of emissions for the last year using the indications of the OECD/IPCC methodology and given methodologies of current information updating. National Fund of Environmental Protection, Warsaw (non-published)
[22] Gawlik L., Grzybek I. (2001). Detailed investigations into emission sources and capture for the inventory of greenhouse gas emissions for 1999 with respect to fugitive emissions from the coal system; Cracow
[23] PIG (2008). Balance of resources of minerals and underground waters in Poland. State for the year 2007. State Geological Institute, Warsaw
[24] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec
[25] PIG (2008). Balance of resources of minerals and underground waters in Poland. State for the year 2007. State Geological Institute, Warsaw

Table 2.2. Analysis of methane emission factors

Emissions	Gawlik et al.[26], 1994		Gawlik and Grzybek[27], 2001		Kwarciński et al[28], 2005	
	Nm^3 CH_4 /t of coal	Gg CH_4 /t of coal	Nm^3 CH_4 /t of coal	Gg CH_4 /t of coal	Nm^3 CH_4 /t of coal	Gg CH_4 /t of coal
ventilation	6.0050	4.0234	6.4430	4.3168	5.8011	3.8868
from methane drainage	NE	NE	0.5962	0.3994	0.9927	0.6651
from post-mining processes	1.4810	0.9923	1.0200	0.6834	0.4288	0.2873
from production wastes	0.0649	0.0435	0.0630	0.0422	0.0289	0.0194
From abandoned mines	NE	NE	0.0489	0.0328	NE	0.0000

NE – not estimated

After the analysis the selection of emission factors was carried out for ventilation systems, methane drainage (degasification) systems, post-exploitation (post-extraction) processes, production wastes and from abandoned mines, for individual years in the period 1988-2007, basing on the above-mentioned sources (National emissions inventory [29] 2009).

In conformity with the procedure, for the solid fuel sector an analysis of uncertainty of data in accordance with the international guidelines included in the IPCC[30] guidelines (2000) and determined as the methodology *Tier 1* has been carried out. In the *National inventory*... (2009) the results of this analysis were recapitulated; wider information about the accuracy of data and full uncertainty analysis can be found in the annex to this report.

The uncertainty counted for individual categories of sources indicates the value 41.9% for the subcategory *B.1. Solid fuels,* in which also methane emissions from hard coal systems were taken into account. The sources of emissions from all sectors are identified as main emission sources on the basis of the assessment of their emission level and/or trend. The methodology of calculation of main emission sources is consistent with the IPCC methodology (IPCC Good Practice Guidance 2000), Tier 1.

Coal mining in the assessment of the methane emission level indicates the seventh place with respect to the share of methane emissions in 2007 in the total emissions that does not take into consideration the sector 5 and the eighth place with regard to the sector 5. In turn the assessment of the trend for methane emission sources (without regard to sector 5) indicated the fifth place of coal mining and its share amounting to 3.4952 and the sixth place and share of coal mining in the trend amounting to 2.9370, taking into account the sector 5[31].

2.1. Methodology of estimation of methane emissions connected with hard coal exploitation in Poland in the years 2001-2010

[26] Gawlik L. et al. (1994). Determination of greenhouse gas emission sources connected with the exploitation of the coal system (hard and brown coal) along with the determination of emission factors in sources of the emission system, calculation of emissions for the last year using the indications of the OECD/IPCC methodology and given methodologies of current information updating. National Fund of Environmental Protection, Warsaw (non-published)

[27] Gawlik L., Grzybek I. (2001). Detailed investigations into emission sources and capture for the inventory of greenhouse gas emissions for 1999 with respect to fugitive emissions from the coal system; Cracow

[28] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec

[29] National inventory of greenhouse gas emissions and absorption for 2007. Report prepared for the needs of the United Nations Framework Convention on Climate Change and Kyoto Protocol. NATIONAL ADMINISTRATOR OF THE EMISSIONS TRADING SHEME. NATIONAL EMISSIONS INVENTORY CENTRE. Institute of Environmental Protection. Warsaw, May 2009

[30] IPCC (2000). Good Practice Guidance and Uncertainty Management in National GHG Inventories

[31] National inventory of greenhouse gas emissions and absorption for 2007. Report prepared for the needs of the United Nations Framework Convention on Climate Change and Kyoto Protocol. NATIONAL ADMINISTRATOR OF THE EMISSIONS TRADING SHEME. NATIONAL EMISSIONS INVENTORY CENTRE. Institute of Environmental Protection. Warsaw, May 2009

The mentioned in the Report of the National Emissions Inventory Centre (KCIE) and in the publication of the State Geological Institute (PIG[32], 2008) methodology of estimation of methane emissions of the hard coal mines system in Poland is at present recommended and used in order to estimate greenhouse gas emissions.

The hitherto used in national emission inventories methane emission factors for individual sources of the hard coal system (according to Kwarciński[33] (2005), and presented in two methodical works of Gawlik (Gawlik et al[34], 1994, and Gawlik and Grzybek (G&G)[35], 2001) require verification. The results of the work of Kwarciński[36] from the year 2005, in which have been estimated – once again – the emission factors on the basis of very detailed data and measurements refer to the year 2003. In this work a thorough analysis of emission factors was performed, comparing them with the results of previous works. For the needs of the national inventory, emission factors per ton of mined out coal were calculated – these values are available in the publication of the above-mentioned State Geological Institute (PIG[37] 2008).

Both the authors of the above-mentioned works and the IPCC[38] (2006) recommendations regarding the estimation of methane emissions from the hard coal system distinguish:

– methane emissions during the coal exploitation process – underground emissions (ventilation emissions, emissions from degasification systems),
– methane emissions in post-exploitation processes – surface emissions.

Each of the identified emission sources should be treated independently and therefore the estimation from each source is performed separately using the formula:

$$E = Q * W_e \tag{2.1}$$

where:
E – emission quantity from the given emission source (m^3)
Q – activity of the system (*coal output quantity*) (t)
W_e – emission factor (m^3/t of mined out coal)

In such a formulation the emission factor determines the volume of methane liberated into the atmosphere per mass unit (ton) of mined out coal. On account of the requirements of reporting, the methane volume is converted into a mass (Gg) unit with the application of the coefficient of conversion 0.67 (t/million m^3) (Revised[39], 1996).

The recommendations of IPCC (2006) laid high stress on the improvement of assessment of emission factors. According to the degree of recognition of the methane content of mined coal seams and accessibility of investigation results, the following methods of estimation of methane emissions from the hard coal system are recommended:

– 1. method of world averages,
– 2. specific method for the country (coal basin),

[32] PIG (2008). Balance of resources of minerals and underground waters in Poland. State for the year 2007. State Geological Institute, Warsaw
[33] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec
[34] Gawlik L et al. (1994). Determination of greenhouse gas emission sources connected with the exploitation of the coal system (hard and brown coal) along with the determination of emission factors in sources of the emission system, calculation of emissions for the last year using the indications of the OECD/IPCC methodology and given methodologies of current information updating. National Fund of Environmental Protection, Warsaw (non-published)
[35] Gawlik L., Grzybek I. (2001). Detailed investigations into emission sources and capture for the inventory of greenhouse gas emissions for 1999 with respect to fugitive emissions from the coal system, Cracow
[36] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec
[37] PIG (2008). Balance of resources of minerals and underground waters in Poland. State for the year 2007. State Geological Institute, Warsaw
[38] IPCC (1997). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Reference Manual.; IPCC (2000). Good Practice Guidance and Uncertainty Management in National GHG Inventories.; IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories
[39] Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reporting Manual. IPCC/OECD joint Programme

– 3. specific method for individual mines.

These methods differ considerably with respect to the accuracy of emission estimation.

1. The method of world averages (the least of all accurate method) recommends the adoption of emission factors on the level of world averages, the ventilation emission factor on the level of 10 m^3/t (low emissions) up to 25 m^3/t and the emission factor from post-exploitation processes on the level 0.9 m^3/t (low emissions) up to 4.0 m^3/t (high emissions).

2. The specific method for the country (coal basin) is recommended for countries (coal basins), where we have at our disposal a limited quantity of data which, however, enable to take into account a different characteristics of gas conditions in individual basins. In this case for ventilation emission estimation it is recommended to use the rectilinear regression equation:

$$W_w = a_0 + a_1 * M_{avg} \tag{2.2}$$

where:

W_w - ventilation emission factor (m^3/t),

a_0, a_1 – equation coefficients,

M_{avg} – average methane content of mined coal (m^3/t).

3. The specific method for mines can be used in the case of accessibility to detailed measurement results of the methane content of coal seams and data related to methane emissions from mines.

In the Poland the *ventilation emission* factors for individual mines can be calculated on the basis of reports of mine ventilation services, included among other thinks in the yearly *Annual Report*…[40] (2002-2011). The total emissions in the case of hard coal mines in Poland constitute the sum of the ventilation emissions and methane capture by degasification systems.

The emissions from *methane drainage systems* in this method are understood as the difference between the quantity of methane captured by methane drainage systems and methane used, at the same time required is the presentation of the estimation methodology and separate pointing out of this part of methane emissions, which would not occur in the case of lack of methane drainage.

2.2. Estimation of methane emissions connected with hard coal exploitation in Poland

The essential basis of the methodology of estimation of methane emissions from hard coal mines in Poland constitutes the study of Kwarciński[41] from the year 2005 and study of the "National Study of Sources and Capture of Greenhouse Gases in Poland", carried out in 1995. In these works on the basis of data from the years 1990 – 1992 the mean methane emission factors for all identified emission sources in the scale of the country were assessed. These factors constituted the basis of methane emission estimations from the hard coal system performed for the year 1988 (base year) and for the next years, in detail for the year 2003.

The inventory methodology of methane emissions from the hard coal system has been widely described in the methodological works (Gawlik et al.[42], 1994; Gawlik, Grzybek 1995[43];

[40] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011

[41] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec, 2005.

[42] Gawlik L. et al. (1994). Determination of greenhouse gas emission sources connected with the exploitation of the coal system (hard and brown coal) along with the determination of emission factors in sources of the emission system, calculation of emissions for the last year using the indications of the OECD/IPCC methodology and given methodologies of current information updating. National Fund of Environmental Protection (non-published)

[43] Gawlik L., Grzybek I (1995). Methodology of estimation of methane emissions connected with coal exploitation in Poland. Gospodarka Surowcami Mineralnymi (Mineral Raw Materials Management. Volume II, Booklet 3.

2000[44]; 2001[45]; 2002[46]). On the basis of the above-mentioned works the general assumptions and the methodology of estimation of methane emissions from the hard coal system in Poland can be characterised as follows: *The applied in Poland methodology presented in the above-mentioned elaborations in conformity with IPCC (2006) recommendations can be considered as the emission estimation method specific for the country*.

According to Kwarciński[47] (2005), the course of conduct when estimating methane emissions from the hard coal system in Poland is as follows:

1. Determination of methane emission sources (emitters) from the system.
2. Analysis of accessibility and collecting of necessary data.
3. Polishing up of the methodology of methane emission estimation from individual emission sources. Calculation of emission factors from determined emission sources.

Conc.1. The authors of the above-mentioned works divide the technological process of hard coal exploitation into two stages, distinguishing two independent methane emission stages:

- Underground stage – comprises hard coal mining, process of deposit opening, coal mining and its transport to the surface as well as the methane drainage process.
- Surface stage – comprises the process of coal mechanical preparation, storage and transport up to its final utilisation.
- *As additional surface methane emission source the authors identify dumping of production wastes (rock).*

Conc.2. As necessary for the development of the methodology of emission estimation from the hard coal system the following basic data were adopted:

- quantity of coal output from individual mines (*Annual Report* [48]…2002-2011),
- measurement results of residual methane content of mines (Kwarciński[49] 2005),
- measurement results of absolute methane content, quantity of methane capture by degasification systems as well as utilization and losses of captured methane (*Annual Report* [50]…2002-2011),
- quantity of production wastes stored on the surface (Statistical Year-book…[51] 2002-2010; Environmental Protection[52]…2011) and content of coal substance in production wastes (waste rocks).

Conc.3. The approach to methane emission changeability in exploited hard coal mines is based on values of the methane content in mines presented in the *Annual Report* [53]…2002-2011). According to Kwarciński[54] (2005), the use of values of the methane content of mined coal seams in CMM mines considerably authenticates the methane emission estimation.

3. Modification of the methodology of methane emission estimation connected with hard coal exploitation in Poland

[44] Gawlik L., Grzybek I. (2000). Investigation results and recommendations for uncertainty reduction and clarity improvement of inventory of fugitive methane emissions from the hard coal system. Workshop: Improvement of National Inventory of Greenhouse Gases in Poland FEWE, Warsaw
[45] Gawlik L., Grzybek I. (2001). Detailed investigations into emission sources and capture for the inventory of greenhouse gas emissions from the coal system; Cracow
[46] Gawlik L., Grzybek I. (2002). Estimation of methane emissions in Polish Basins (Hard Coal System). Polish Academy of Sciences. Publ. IGSMiE. Cracow
[47] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec, 2005.
[48] *Annual Report* (for the years 2001-2010) on the State of Basis Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
[49] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec, 2005.
[50] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
[51] Statistical Year-book of the Silesian Voivodeship (2001-2010). Statistical Office in Katowice, Katowice
[52] Environmental Protection in the Silesian Voivodeship in the Years 2007-2010. Statistical Office in Katowice. Katowice 2011
[53] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
[54] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec, 2005.

The restructuring process of the coal industry in Poland caused that the determined emission factors (for the year 1992), and especially country averages became outdated to a great extent. This was the reason of performed new emission estimation (Gawlik, Grzybek[55], 2002), taking into consideration organisational changes connected with the restructuring of the coal industry in the years 1992-1998. The new estimation was based on the same data, assumptions and theoretical bases as this carried out for the state of the year 1992.

In spite of the modification of methane emission assessment carried out in 2005 (according to Kwarciński[56]), as before the method of emission estimation evokes a number of doubts. These doubts were announced already by the authors of the method (Gawlik, Grzybek[57], 2002). The authors of the cited methodology perceive the uncertainly reasons of methane emissions from the hard coal system in the method itself (internal sources) as well as in the practice of its application and changes caused by the restructuring of hard coal mining.

The proposed new methodology of estimation of methane emissions from hard coal mines, in conformity with the nomenclature applied by ICPP (2006) should be counted among specific methods for mines.

Underground stage – the estimation of methane emissions from their individual identified sources was conducted separately, in an independent manner. All carried out calculations intended to the determination of dependence coefficients of emissions from individual identified sources with the data: quantity of coal output and methane content of the mine. As absolute methane emissions of a mine was adopted the sum of ventilation emissions and this part of methane captured by methane drainage systems, which was acknowledged as capture of methane, which would emit into the atmosphere during exploitation.

Modification of methods IPCC[58] (2006) of estimating methane emission from ventilation systems and degasification systems of hard coal mines (active ones and abandoned ones) in Poland assume that methane emission factor (EF) is calculated on the basis of methane coal mine (CMM Coal Methane) output and actual values of absolute methane content.

Estimation of ventilation emissions - The ventilation emissions E_w for individual mines were calculated on the basis of the formula:

$$E_w = W_e * Q_w \qquad (3.1)$$

where:
- Q_w – Hard coal output in the CMM Coal Mines (t),
- W_e – ventilation emission factor (m^3 CH_4/t of coal).

Estimation of methane emissions from methane drainage systems – is the value of emissions of losses of captured methane adopted on the basis of measurements carried out in mines. These emissions are also determined as the difference between the captured and utilised methane.

The range of data applied in the new proposed in the present study methodology of estimation of methane emissions from the hard coal system concern data in the scale of mines. The range and sources of origin of the considered information and measurement results are as follows:

55 Gawlik L., Grzybek I. (2002). Estimation of methane emissions in Polish Basins (Hard Coal System). Polish Academy of Sciences. Publ. IGSMiE. Cracow
56 Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec, 2005.
57 Gawlik L., Grzybek I. (2002). Estimation of methane emissions in Polish Basins (Hard Coal System). Polish Academy of Sciences. Publ. IGSMiE. Cracow
58 IPCC (2006). Guidelines for National Greenhouse Gas Inventories

1. The quantity of methane from ventilation systems, given annually by every hard coal mine (in m^3 CH_4/year) – was adopted on the basis of data presented in the *Annual Report* [59]…(2002-2011).
2. The quantity of methane captured in the mine, given annually by every hard coal mine in m^3 CH_4/year) – was adopted on the basis of data presented in the *Annual Report* [60]…(2002-2011).
3. The quantity of methane emitted into the atmosphere from methane drainage systems, given annually by every hard coal mine (in m^3 CH_4/year) – was adopted on the basis of data presented in the *Annual Report* [61]…(2002-2011).
4. Yearly average temperature of ventilation air (return air) measured in the point of volume measurement. Because of the lack of data from direct measurements, the temperature equal to 30 ^oC was adopted (according to Kwarciński[62] 2005).
5. The yearly average temperature of mine gas emitted from methane drainage systems is measured in the point of its volume measurement. Because of the lack of data from direct measurement, the temperature equal to 30^0 C was adopted (according to Kwarciński[63] 2005).
6. The quantity of hard coal exploitation (Q_w, tons) was adopted on the basis of data presented in the *Annual Report* [64]…(2002-2011).

Inventory of methane emissions from ventilation systems of hard coal mines in Poland

The ventilation emissions were estimated on the basis of data specified in the *Annual Report* [65]… in individual years 2001-2010, in accordance with the recommended methodology according to Kwarciński[66] (2005).

The final value of ventilation methane emissions is obtained after the conversion of pointed out by individual CMM mines, and calculated on the basis of the above-mentioned relationship, methane emission values into standard conditions (293 ^oK). This conversion is carried out by help of the formula:

$$E_{w(N)} = E_w * 293 / (273 + t_p) \quad (3.2)$$

where:

$E_{w(N)}$ – ventilation emissions converted into standard conditions (20 ^oC), [million m^3],
E_w – ventilation emissions [million m^3],
t_p – yearly average temperature of ventilation air [^oC].

The specification of final ventilation emission values (converted into standard conditions – 293 ^oK) and calculated emission factors in individual hard coal mines contain the Table 4.1.
Ventilation emissions from mines, that did not point out ventilation emissions, were not estimated.

[59] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
[60] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
[61] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
[62] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec, 2005.
[63] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec, 2005.
[64] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
[65] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
[66] Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec, 2005.

Inventory of methane emissions from methane degasification systems of hard coal mines in Poland

Emissions from methane drainage systems (E_o) of each of the CMM mines, where methane drainage is conducted (otherwise called loss emissions) are calculated as the difference of the quantity of captured methane (M_{ui}) and quantity of utilized methane (M_{wi}) (or burnt):

$$E_o = M_{ui} - M_{wi} \quad [\text{million m}^3\ CH_4] \qquad (3.3)$$

The final value of methane emissions from degasification systems is obtained after the conversion of pointed out through individual mines values of methane emissions into standard conditions (293 ^oK). This conversion is carried out by help of the formula:

$$E_{o(N)} = E_o * 293 / (273 + t_p) \qquad (3.4)$$

where:
$E_{o(N)}$ – emissions from methane drainage systems converted into standard conditions (20^{o}C), [million m^3],
E_o - emissions from methane drainage systems [million m^3],
t_p – yearly average temperature of mine gas [^{o}C].

The emissions from methane drainage systems were estimated on the basis of data specified in the *Annual Report*[67]... in individual years 2001-2010, in accordance with the recommended methodology according to Kwarciński[68] (2005). In Table 4.1 the values of emission factors for CMM mines in each of the analysed years were specified.

4. Verification and updating the proposed methods IPCC 2006 of estimating methane emission from ventilation systems and degasification systems of hard coal mines in Poland

The proposed new methodology of estimation of methane emissions from output CMM coal mines, in conformity with the nomenclature applied by ICPP (2006) should be counted among specific methods for mines. The emissions from both sources are based on the results of measurements and investigations conducted in individual hard coal mines. The calculated average national emission factors for the years 2001-2010 amounted respectively to (Table 4.1):

- for ventilation emissions - 8.871 m^3/t (7.010-11.050 m^3/t),
- for emissions from methane drainage systems - 1.545 m^3/t (0.990 – 2.137 m^3/t.

The inventory of methane emissions in Polish hard coal mines has pointed out that the hard coal system generates methane from four sources. On the basis of the above fact the following division has been carried out into methane emissions from coal output processes (ventilation emissions and from degasification systems) and emissions from post-mining processes (emissions from post-mining processes and emissions from post-production wastes). Because in the analysed period 2001-2010 the measurement of methane emissions from mines concerned also an abandoned mine (Niwka-Modrzejów colliery), the quantity and share of methane emissions from this mine have been taken into account in the collective analyses regarding the years 2001-2002.

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67 *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011
68 Kwarciński J. (2005). Assessment of real methane emissions into the atmosphere caused by hard coal exploitation. State Geological Institute, Sosnowiec, 2005.

Methane emissions from ventilation systems and drainage (degasification) systems of hard coal mines in Poland in the years 2001-2010 shows table 4.1.

Table 4.1. Specification of estimations of methane emissions from the hard coal system in Polish mines in the years 2001-2010

YEAR	**Type of emissions**	**Output of CMM coal mines**	**Methane emissions in standard conditions**	**Emission factor**	**Methane emissions**
		milion t	milion Nm^3	m^3 CH_4/t	Gg
2001	Ventilation emissions	**72.366**	515.314	7.010	345.260
	Emissions from degasification systems		85.185	0.990	57.074
	Underground coal mining industry		**600.499**	**8.000**	**402.334**
2002	Ventilation emissions	**72.129**	538.660	7.284	360.902
	Emissions from degasification systems		82.894	0.996	55.539
	Underground coal mining industry		**621.554**	**8.280**	**416.441**
2003	Ventilation emissions	**65.708**	548.487	8.457	367.486
	Emissions from degasification systems		96.612	1.353	64.730
	Underground coal mining industry		**645.099**	**9.809**	**432.217**
2004	Ventilation emissions	**69.167**	556.020	7.640	372.534
	Emissions from degasification systems		102.569	1.281	68.721
	Underground coal mining industry		**658.589**	**8.921**	**441.255**
2005	Ventilation emissions	**67.347**	576.200	8.075	386.054
	Emissions from degasification systems		107.446	1.500	71.989
	Underground coal mining industry		**683.646**	**9.575**	**458.043**
2006	Ventilation emissions	**64.518**	537.592	8.332	360.187
	Emissions from degasification systems		126.870	1.966	85.003
	Underground coal mining industry		**664.462**	**10.298**	**445.190**
2007	Ventilation emissions	**62.465**	590.090	9.427	395.361
	Emissions from degasification systems		99.630	1.637	66.752
	Underground coal mining industry		**689.720**	**11.064**	**462.112**
2008	Ventilation emissions	**57.537**	586.677	10.288	393.074
	Emissions from degasification systems		113.816	2.137	76.256
	Underground coal mining industry		**700.492**	**12.426**	**469.330**
2009	Ventilation emissions	**53.271**	576.243	11.150	386.083
	Emissions from degasification systems		96.990	1.815	64.983
	Underground coal mining industry		**673.233**	**12.966**	**451.066**
2010	Ventilation emissions	**52.184**	559.852	11.050	375.101
	Emissions from degasification systems		91.671	1.777	61.420
	Underground coal mining industry		**651.524**	**12.826**	**436.521**

In spite of the coal output reduction in the Polish mining industry, since the year 2008 the average emission factor from the hard coal system maintains on a constant level. The performed analyses betray also the permanent trend of methane emissions in the entire analysed period of years 2001-2010 (Fig. 4.1).

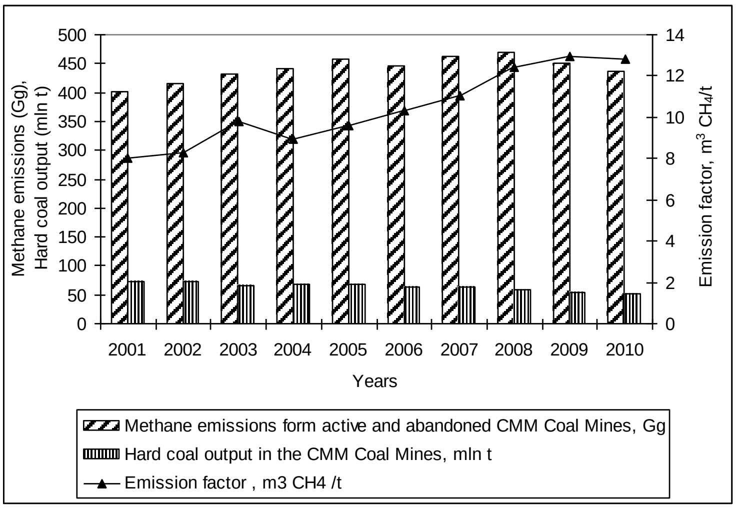

Fig. 4.1. Methane emissions and emission factor for inventory years 2001-2010 from the exploitation of hard coal in Poland

The main assumption of the calculations and methane emission inventory (Table 4.1), was the approach in accordance with IPCC[69] (2006) with the use of country specific methods (Tier 2). A detailed analysis of methane emission from coal mines in Poland showed there is a significant difference between the total volume of production and the volume of production in methane mines only (Table 4.2). That is why the analysis of variability coefficients of methane emission in hard coal mines in Poland between 2001-2010 was made. It considered the total volume of production and the volume of production in methane mines as the basis for the analyses.

In Table 4.2 the total coal output value and coal output in methane mines value were collected, each of the years 2001-2010 was assigned its variability coefficient. On the basis it was concluded: taking into consideration output of methane coal mines the uncertainty of estimating methane emission activity decreases by approx *29.52%.*

Table 4.2. Uncertainty in measurement of methane emission activity in hard coal mines in Poland

Years	Hard coal output in the Coal Mines	Hard coal output in the CMM Coal Mines	Uncertainty in measurement of methane emission activity
	(milion tonnes)	(milion tonnes)	%
2001	102.78	72.37	27.36
2002	102.07	72.13	27.13
2003	100.41	65.71	34.34
2004	99.17	69.17	26.72
2005	97.17	67.35	27.15
2006	94.27	64.52	29.61

[69] IPCC (2006). Guidelines for National Greenhouse Gas Inventories

2007	87.40	62.47	27.54
2008	83.40	57.54	30.70
2009	77.27	53.27	32.00
2010	76.15	52.18	32.66

On the basis of the above data, all the calculations of methane emission in Poland were made, taking as the basic value – **production of hard coal only in methane coal mines.** On the basis of the methodology proposed to estimate methane emission in Polish coal mines (in the inventory report of Task 1.4 project) the final collation of the obtained values was presented. The values meet IPCC[70] (2006) requirements, but they are based on actual data from methane coal mines. The differences in estimating methane ventilation emission in Polish coal mines are a result of the difference between the actual value of methane ventilation emission in Polish coal mines and the value calculated according to IPCC 2006 (Table 4.3). The value of emission factor in both cases is an identical value.

Table 4.3 The difference values for methane emissions vented from coal mines according to the Polish methodology and IPCC (2006)

Years	**Hard coal output in the CMM Coal Mines, milion tonnes**	**Emission Factor, m^3/tonne**	**Actual emissions of methane according to the Polish methodology, Gg**	**Methane Emissions by IPCC, Gg**	**The difference values for emissions, Gg**	**Relative error of predictions by IPCC, %**
2001	72.370	7.010	345.260	339.900	5.360	1.552
2002	72.130	7.284	360.902	352.015	8.887	2.463
2003	65.710	8.457	367.486	372.325	-4.839	-1.317
2004	69.170	7.640	372.534	354.067	18.467	4.957
2005	67.350	8.075	386.054	364.380	21.674	5.614
2006	64.520	8.332	360.187	360.179	0.008	0.002
2007	62.470	9.427	395.361	394.566	0.795	0.201
2008	57.540	10.288	393.074	396.621	-3.547	-0.902
2009	53.270	11.150	386.083	397.954	-11.871	-3.075
2010	52.180	11.050	375.101	386.315	-11.214	-2.989
Average emission values:		**8.871**	**374.204**	**371.832**	**2.372**	**0.651**

On the basis of the above calculations the relative error of predictions of methane emission estimation in coal mines according to the Polish method and proposed by IPCC 2006 is approximately 0.651.

In general it is necessary to assume that IPCC 2006 guidelines are appropriate to assess methane emission. Yet it is necessary to emphasize the fact that the estimation method has to refer only to the methane coal mines output and be based on the measurements of methane content. The basis are data on uncertainty of estimating methane emission activity. The average

[70] IPCC (2006). Guidelines for National Greenhouse Gas Inventories

value of uncertainty of methane emission activity decreased by approximately 29.52% when it was calculated with methane coal mines output instead of total output.

Updating the proposed methods (IPCC[71] 2006) of estimating methane emission from ventilation systems and degasification systems of hard coal mines (active ones and abandoned ones) in Poland assume that methane emission factor (EF) is calculated on the basis of methane coal mine output and actual values of absolute methane content.

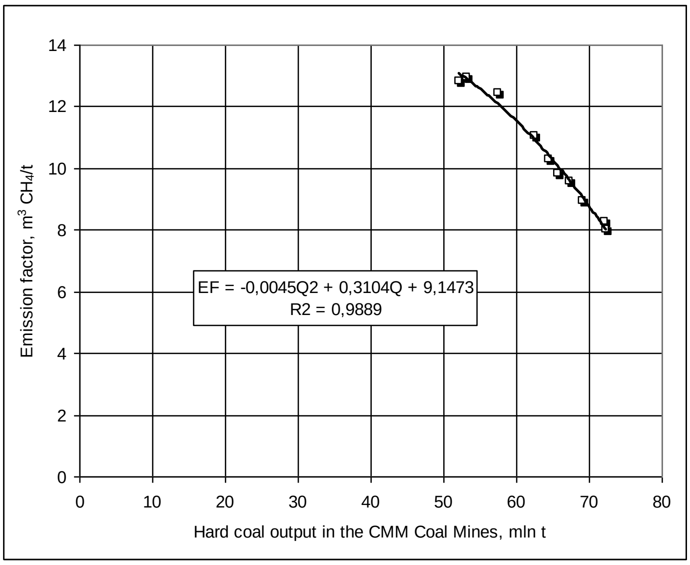

Fig. 4.2. Distribution of mining methane emission factor for hard coal mines in Poland between 2001-2010

Using the results of *Annual Report*[72] (for the years 2001-2010) national emission factors for the following emission sources in hard coal mines were determined:

- from ventilation systems,
- from methane drainage systems.

In Fig 4.2 distribution of emission factors (for 2 sources) between 2001-2010 from methane coal mines in Poland is presented. It shows a trend in agreement with the distribution of polynomial function of fitness $R^2 = 0.989$. The result of verifying the method of estimating methane emission for Polish coal mines is the equation of methane emission factor in the following form:

$$EF = -0.0045 \cdot Q^2 + 0.3104 \cdot Q + 9.1473 \quad (4.1)$$

where :

EF - Emission Factor, m^3/tonne

Q - Hard Coal Output in the CMM Coal Mines, milion tonnes

4. References

[1] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011

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[71] IPCC (2006). Guidelines for National Greenhouse Gas Inventories

[72] *Annual Report* (for the years 2001-2010) on the State of Basic Natural and Technical Hazards in the Hard Coal Mining Industry. Central Mining Institute, Katowice 2002-2011

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Inwentaryzacja emisji metanu z układów wentylacyjnych i z układów odmetanowania kopalń węgla kamiennego w Polsce w latach 2001-2010

Streszczenie

Z rozeznania i przeglądu literaturowego dotyczącego zagadnień związanych z emisją metanu w Polsce wynika, że w 2009 roku opublikowano Raport Krajowej Inwentaryzacji Emisji i Pochłaniania gazów cieplarnianych za rok 2007[73] sporządzony celem wypełnienia zobowiązań Polski zgodnie z wymaganiami artykułu 3.1 decyzji 280/2004/WE Parlamentu Europejskiego i Rady z dnia 11 lutego 2004 roku dotyczącej mechanizmu monitorowania emisji gazów cieplarnianych Wspólnoty oraz wdrażania Protokołu z Kioto, jak również na potrzeby Ramowej konwencji Narodów Zjednoczonych w sprawie zmian klimatu (UNFCCC) oraz jej Protokołu z Kioto.

Z *Raportu Krajowej Inwentaryzacji...* wynika, że brak jest danych szczegółowych dotyczących wskaźników emisji metanu z kopalń węgla kamiennego dla Polskiego górnictwa. W związku z tym, przygotowano i obliczono szczegółowo emisje metanu z kopalń metanowych Górnośląskiego Zagłębia Węglowego w Polsce. Zastosowana metodyka szacowania metanu z kopalń GZW, wykonana została dla dwóch podstawowych źródeł jego emisji. Obliczono emisję metanu w trakcie procesu eksploatacji węgla jako emisję wentylacyjną oraz emisję z układów odgazowania. Takie podejście wynikało z wytycznych IPCC[74] z roku 2006.

Aktualizacja proponowanych metod IPCC (2006) szacowania emisji metanu z układów wentylacyjnych i z układów odmetanowania kopalń węgla kamiennego (czynnych i zlikwidowanych) w Polsce polega na założeniu, że wskaźnik emisji metanu (EF) obliczamy w oparciu o wydobycie z koplań metanowych oraz rzeczywiste wielkości metanowości bezwzględnej. Rezultat modyfikacji metody szacowania emisji metanu z procesów górniczych dla polskich metanowych koplań węgla kamiennego to równanie wskaźnika emisji metanu EF.

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