Worksheet on ancillary emissions of methane and CO_2: coal mining and related operations

Background calculations on ancillary emissions of methane and carbon dioxide

Heede, CMS
28-Dec-12

Coal fugitive methane: IPCC Tier 1 Guidelines values

IPCC Guidelines 2006: default values for CH_4 and CO_2 emissions from Flaring, Venting, and Fugitives from Natural Gas Production and Oil Production

Intergovernmental Panel on Climate Change (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Volume 2: Energy, Chapter 4: Fugitive Emissions, Geneva; www.ipcc-nggip.iges.or.jp/public/2006gl

Table 1	m^3 CH_4 per tonne coal mined			
	Low	Average	High	
Underground mining	m^3/t mined	m^3/t mined	m^3/t mined	
Mining	10.00	**18.00**	25.00	39%
Post-mining	0.90	**2.50**	4.00	60%
Total	10.90	**20.50**	29.00	41%
Surface mining				
Mining	0.30	**1.20**	2.00	67%
Post-mining	-	**0.10**	0.20	100%
Total	0.30	**1.30**	2.20	69%
UG/SF	36.33	15.77	13.18	-16%

Table 1 * 0.67 (kgCH_4/m^3)

Table 2	kg CH_4 per tonne coal mined				
	Low	Average	High		
Underground mining	kg CH_4/t mined	kg CH_4/t mined	kg CH_4/t mined		
Mining	6.70	**12.06**	16.75		
Post-mining	0.60	**1.68**	2.68		
Total	7.30	**13.74**	19.43	6.43	46.8%
				5.70	41.5%
Surface mining					
Mining	0.20	**0.80**	1.34		
Post-mining	-	**0.07**	0.13		
Total	0.20	**0.87**	1.47	0.67	76.9%
UG/SF	36.33	15.77	13.18	0.60	69.2%

Table 3	CO_2e per tonne coal mined			
	Low	Average	High	
Underground mining	kg CO_2e/t mined	kg CO_2e/t mined	kg CO_2e/t mined	
Mining	140.70	253.26	351.75	39%
Post-mining	12.66	35.18	56.28	60%
Total	153.36	288.44	408.03	41%
Surface mining				
Mining	4.22	16.88	28.14	67%
Post-mining	-	1.41	2.81	
Total	4.22	18.29	30.95	

Table 4	kg CO_2e per tonne coal mined			
	Low	Average	High	
Underground mining	kg CO_2e/t mined	kg CO_2e/t mined	kg CO_2e/t mined	
Mining & post-mining	153.36	288.44	408.03	
Combustion factor	2,128.93	2,128.93	2,128.93	
Emission rate	7.20%	**13.55%**	19.17%	methane emissions as percent adder to combustion emissions
Surface mining				
Mining & post-mining	4.22	18.29	30.95	
Combustion factor	2,128.93	2,128.93	2,128.93	
Emission rate	0.20%	**0.86%**	1.45%	methane emissions as percent adder to combustion emissions
UG & SUR, averaged	3.70%	7.20%	10.31%	methane emissions as percent adder to combustion emissions

Table 5	kg CO_2e per tonne coal mined		
	Low	Average	High
Combined mining	kg CO_2e/t mined	kg CO_2e/t mined	kg CO_2e/t mined
UG & SUR, averaged	78.79	153.36	219.49
Combustion factor	2,129	2,129	2,129
Emission rate	3.70%	**7.20%**	10.31%

	Table 6	kg CH_4/ t coal mined converted to kg CH_4/t CO_2			
		Low	Average	High	
	Combined mining	kg CH_4/t CO_2 comb.	kg CH_4/t (or tCO_2)	kg CH_4/tonne	
	Underground	7.30	13.74	19.43	kg CH_4/t mined
	Surface	0.20	0.87	1.47	kg CH_4/t mined
	Total	7.50	14.61	20.90	kg CH_4/t mined
	Average	3.75	7.30	10.45	kg CH_4/t mined
	Coal combustion EF	2.13	2.13	2.13	tCO_2 emitted/t coal combusted
	Methane rate, CH_4	**1.76**	**3.43**	**4.91**	kg CH_4/tCO_2 from combusted coal
	Methane rate, CO_2e	37.01	**72.04**	103.10	kg CO_2e/tCO_2 from combusted coal
Adjusted for mining method.	Methane rate, adjuste	**2.10**	**4.03**	**5.75**	kg CH_4/tCO_2 from combusted coal
Adjusted for mining method.	Methane rate, adjuste	44.02	84.73	120.81	kg CO_2e/tCO_2 from combusted coal

linked to summary table 9, and thereto SumRanking.xls

Table 7	
Mining method	Percent
Underground	60%
Surface	40%

World Coal Institute, London.

Table 8	Combustion factors for fuels				
	Combustion EF	Units		Combustion EF	Converted to
Coal	2.1289	MtCO_2/Mt thermal coal		2,128.93	kg CO_2/tonne

linked to emission factor in SumCoal.xls

IPCC 2006 Guidelines, vol. 2, chapter 4: Fugitive emissions; Surface mining: fugitive methane, page 4.19.

Listed conversion factor: 0.67 kg CH_4 per m^3 CH_4

No discussion of fugitive CO_2.

Except for page 4.10:

Low temperature oxidation:

"Oxidation of coal when it is exposed to the atmosphere by coal mining releases CO_2. This source will usually be insignificant when compared with the total emissions from gassy underground coal mines.
Consequently, no methods are provided to estimate it. Where there are significant emissions of CO_2 in addition to methane in the seam gas, these should be reported on a mine-specific basis."

Coal fugitive methane: IPCC Tier 1 Guidelines values

4.1.3.2 Choice of emission factors for underground mines

MINING

Tier 1 Emission Factors for underground mining are shown below. The emission factors are the same as those described in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (BCTSRE, 1992; Bibler et al, 1991; Lama, 1992; Pilcher et al, 1991;USEPA, 1993a,b and Zimmermeyer, 1989).

EQUATION 4.1.3
TIER 1: GLOBAL AVERAGE METHOD – UNDERGROUND MINING – BEFORE ADJUSTMENT FOR ANY METHANE UTILISATION OR FLARING

Ch_4 emissions = CH_4 Emission Factor • Underground Coal Production • Conversion Factor

Where units are:

Methane Emissions (Gg $year^{-1}$)

CH_4 Emission Factor (m^3 $tonne^{-1}$)

Underground Coal Production (tonne $year^{-1}$)

2006 IPCC Guidelines for National Greenhouse Gas Inventories 4.11

Volume 2: Energy

Emission Factor:

Low CH_4 Emission Factor = 10 m^3 $tonne^{-1}$

Average CH_4 Emission Factor =18 m^3 $tonne^{-1}$

High CH_4 Emission Factor = 25 m^3 $tonne^{-1}$

Conversion Factor:

This is the density of CH_4 and converts volume of CH_4 to mass of CH_4. The density is taken at 20°C and 1 atmosphere pressure and has a value of 0.67 • 10^{-6} Gg m^{-3}.

Countries using the Tier 1 approach should consider country-specific variables such as the depth of major coal seams to determine the emission factor to be used. As gas content of coal usually increases with depth, the low end of the range should be chosen for average mining depths of <200 m, and for depths of > 400 m the high value is appropriate. For intermediate depths, average values can be used.

For countries using a Tier 2 approach, basin-specific emission factors may be obtained from sample ventilation air data or from a quantitative relationship that accounts for the gas content of the coal seam and the surrounding strata affected by the mining process, along with raw coal production. For a typical longwall operation, the amount of gas released comes from the coal being extracted and from any other gas-bearing strata that are located within 150 m above and 50 m below the mined seam (*Good Practice Guidance*, 2000).

IPCC 2006: Underground mining: fugitive methane, page 4.11

POST-MINING EMISSIONS

For a Tier 1 approach the post-mining emissions factors are shown below together with the estimation method:

EQUATION 4.1.4
TIER 1: GLOBAL AVERAGE METHOD – POST-MINING EMISSIONS – UNDERGROUND MINES

Methane emissions = CH_4 Emission Factor • Underground Coal Production • Conversion Factor

Where units are:

Methane Emissions (Gg $year^{-1}$)

CH_4 Emission Factor (m^3 $tonne^{-1}$)

Underground Coal Production (tonne $year^{-1}$)

Emission Factor:

Low CH_4 Emission Factor = 0.9 m^3 $tonne^{-1}$

Average CH_4 Emission Factor =2.5 m^3 $tonne^{-1}$

High CH_4 Emission Factor = 4.0 m^3 $tonne^{-1}$

TABLE 4.1.5
TIER 1 – ABANDONED UNDERGROUND MINES
DEFAULT VALUES - PERCENTAGE OF COAL MINES THAT ARE GASSY

Time Interval	Low	High
1900-1925	0%	10%
1926-1950	3%	50%
1950-1976	5%	75%
1976-2000	8%	100%
2001-Present	9%	100%

IPCC 2006, page 4.24

4.1.4.2 Emission factors for surface mining

Although measurements of methane emissions from surface mining are increasingly available, they are difficult to make and at present no routine widely applicable methods exist. Data on *in situ* gas contents before overburden removal are also scarce for many surface mining operations.

The Tier 1 emission factors are shown together with the estimation method in Equation 4.1.7.

EQUATION 4.1.7
TIER 1: GLOBAL AVERAGE METHOD – SURFACE MINES

Methane emissions = CH_4 Emission Factor •Surface Coal Production • Conversion Factor

Where units are:

Methane Emissions (Gg $year^{-1}$)

CH_4 Emission Factor (m^3 $tonne^{-1}$)

Surface Coal Production (tonne $year^{-1}$)

Emissions Factor:

Low CH_4Emission Factor = 0.3 m^3 $tonne^{-1}$

Average CH_4 Emission Factor = 1.2 m^3 $tonne^{-1}$

High CH_4 Emission Factor = 2.0 m^3 $tonne^{-1}$

POST-MINING EMISSIONS – SURFACE MINING

For a Tier 1 approach the post-mining emissions can be estimated using the emission factors shown in Equation 4.1.8.

EQUATION 4.1.8
TIER 1: GLOBAL AVERAGE METHOD – POST-MINING EMISSIONS – SURFACE MINES

Methane emissions = CH_4 Emission Factor • Surface Coal Production • Conversion Factor

Where units are:

Methane Emissions (Gg $year^{-1}$)

CH_4 Emission Factor (m^3 $tonne^{-1}$)

Surface Coal Production (tonne $year^{-1}$)

Emission Factor:

Low CH_4 Emission Factor = 0 m^3 $tonne^{-1}$

Average CH_4 Emission Factor = 0.1 m^3 $tonne^{-1}$

High CH_4 Emission Factor = 0.2 m^3 $tonne^{-1}$

Conversion Factor:

This is the density of CH_4 and converts volume of CH_4 to mass of CH_4. The density is taken at 20°C and 1 atmosphere pressure and has a value of 0.67 • 10^{-6} Gg m^{-3}.

The average emission factor should be used unless there is country-specific evidence to support use of the low or high emission factor.

IPCC 2006: Surface mining: fugitive methane, page 4.18

Table 9

Final coal mining methane rates

Table of factors calculated on this worksheet and linked to the entity summary worksheet (SumRanking.xls)

	Final coal mining methane rates			Draft coal mine CO2 liberation rates		
	Methane			Carbon Dioxide		
	Coal mining emissions			Coal mining emissions		
	kg CH4/t coal	kg CH4/t CO2	kg CO2e/t CO2	kg CO2/t C	kg CO2/t CO2	kg CO2/t coal
IPCC values: (applied 22Dec12)	8.59	4.03	84.73	4.52	1.23126	2.62
	linked to Table 10	linked to Table 6	Cell F146 * 21	speculative estimate by CMS, Jul12.		
		IPCC average value	(per IPCC SAR)	Excluded emissions from vented CO2		
	adjusted for mining method, Table 7			426.6 MtCO2		
Pre-IPCC values: (Dec12)	8.06	3.90	81.92			
	linked to Table 18	linked to Table 18	Cell F142 * 21			
		linked to SumRanking	(per IPCC SAR)			

Summary of Ancillary methane factors for coal operations used in SumRanking.xls

Othere sources of methane emissions rates, coal mining

Table 10

				Donetski Basin	Kuznetski	Karag. & Ekib.	Pechorski	Average	Average
				kg CH4/t	kg CH4/t	kg CH4/t	kg CH4/t	kg CH4/t	kgCH4/tCO2
Andronova & Karol (1993)	USSR, 1986		Low	0.7	0.7	8.0	2.0	2.9	1.53
			High	23.0	14.0	11.0	24.0	18.0	9.67
			Average	11.9	7.4	9.5	13.0	10.4	5.60
			kgCH4/tCO2	6.36	3.95	5.10	6.98	5.60	na

Line above: CH4 emissions divided by CO2 emissions (ave util coal) per tonne coal mined

Table 11 Coal conversions

1 Bcf CH4 =	0.01916 Mt CH4
1 cf CH4 =	19.16 g CH4

Table 12

Ancillary emissions of Methane and Carbon Dioxide in Coal Mining

		D	E	F	G	H	I	J	K	L	N	O	P	Q
							Methane emissions rates							CMS adjusted
		CH4 emissions		CH4 emissions	Coal production		various	underground	surface mines	combined mines	as proportion of product combustion			Coal Coefficient
	Year	Bcf		million t CH4	million tons	million tonnes	cf/ton of coal	kg CH4/t coal	kg CH4/t coal	kg CH4/t coal	kg CH4/t CO2	kg CO2-eq/t CO2	# est	t CO2/t coal
Delucchi, 2003:	US data			Tg CH4		Mt						percent * 10		1.8623
US EPA 1993	1988, low	172.3		3.30	950.0	861.8				3.831	2.06	43.19	1	1.8623
US EPA 1993	1988, high	271.4		5.20	950.0	861.8				6.034	3.24	68.04	2	1.8623
US DOE / EIA 1995	1998	220.2		4.22	950.0	861.8				4.895	2.63	55.20	3	1.8623
Kirchgessner et al	1989	193.2	underground coal	3.70	356.0	323.0		11.462						1.8623
CIAB / Thakur	1990	190.9		3.66	931.0	844.6				4.331	2.33	48.83	4	1.8623
Also cited in Delucchi:	US data													1.8623
EIA, US underground r	1987		underground coal	3.86	372.9	338.3	540.3	11.410						1.8623
EIA, US underground r	1992		underground coal	4.19	407.2	369.4	537.1	11.342						1.8623
EIA, US underground r	1996		underground coal	3.92	407.7	369.9	501.9	10.599						1.8623
EIA, US surface mines	1987		surface coal	0.42	545.9	495.2	40.2	underground	0.848					1.8623
EIA, US surface mines	1992		surface coal	0.46	590.3	535.5	40.7		0.859					1.8623
EIA, US surface mines	1996		surface coal	0.50	655.2	594.4	39.8		0.841					1.8623
EIA, US total coal	1987		surface + undergrounc	4.28	918.8	833.5	229.0		surface	5.135	2.76	57.90	5	1.8623
EIA, US total coal	1992		surface + undergrounc	4.65	997.5	904.9	224.0			5.139	2.76	57.94	6	1.8623
EIA, US total coal	1996		surface + undergrounc	4.42	1,062.9	964.3	192.5			4.584	2.46	51.69	7	1.8623
														1.8623
EIA, US total coal	2004		surface + undergrounc	2.93	1,112.1	1,008.9				2.904	1.56	32.75		1.8623
														1.8623
Andronova & Karol	Russia, 1986	Coal Basin:	Donetski			198.0	low & high	0.7	23.0	11.850	6.36	133.62	8	1.8623
		Coal Basin:	Kuznetski			154.0	low & high	0.7	14.0	7.350	3.95	82.88	9	1.8623
		Coal Basin:	Karagandinski & Ekibastur			143.0	low & high	8.0	11.0	9.500	5.10	107.12	10	1.8623
		Coal Basin:	Pechorski			32.0	low & high	2.0	24.0	13.000	6.98	146.59	11	1.8623
														1.8623
CIAB / Thakur	China, 1990	405.0		7.76	1,190.4	1,079.9				7.186	3.86	81.03	12	1.8623
														1.8623
EPA, Scheehle 2001	OECD		million tonnes CO2-eq	million tonnes CH4	million tons	million tonnes								1.8623
Australia	1990		15.9	0.76	225.8	204.8				3.697	1.98	41.68	13	1.8623
	1995		16.7	0.80	266.5	241.8				3.289	1.77	37.08	14	1.8623
	2000		19.7	0.94	338.2	306.8				3.058	1.64	34.48	15	1.8623
	2005	*coal 2004*	22.6	1.08	391.0	354.7				3.034	1.63	34.22	16	1.8623
Russia	1995		38.2	1.82	270.9	245.7				7.403	3.97	83.47	17	1.8623
	2000		31.9	1.52	264.9	240.3				6.321	3.39	71.27	18	1.8623
	2005	*coal 2004*	31.3	1.49	*308.9*	280.2				5.319	2.86	59.98	19	1.8623
Poland	1990		16.8	0.80	237.1	215.1				3.720	2.00	41.94	20	1.8623
	1995		15.6	0.74	221.2	200.7				3.701	1.99	41.73	21	1.8623
	2000		14.8	0.70	179.5	162.8				4.328	2.32	48.81	22	1.8623
	2005	*coal 2004*	14.1	0.7	*177.7*	161.2				4.165	2.24	46.96	23	1.8623
UK	1990		17.2	0.8	104.1	94.4				8.677	4.66	97.84	24	1.8623
	1995		7.6	0.4	52.5	47.6				7.601	4.08	85.71	25	1.8623
	2000		5.2	0.2	34.7	31.5				7.858	4.22	88.60	26	1.8623
	2005	*coal 2004*	5.0	0.2	*27.0*	24.5				9.704	5.21	109.42	27	1.8623
Ukraine	1995		30.1	1.4	94.6	85.8				16.701	8.97	188.32	28	1.8623
	2000		28.1	1.3	69.1	62.7				21.352	11.47	240.77	29	1.8623
	2005	*coal 2004*	26.1	1.2	69.3	62.8				19.780	10.62	223.05	30	1.8623
USA	1990		87.9	4.2	1,029.1	933.6				4.484	2.41	50.56	31	1.8623
	1995		74.6	3.6	1,033.0	937.1				3.791	2.04	42.75	32	1.8623
	2000		77.9	3.7	1,073.6	974.0				3.809	2.05	42.95	33	1.8623
	2005	*coal 2004*	81.8	3.9	*1,112.1*	1,008.9				3.861	2.07	43.54	34	1.8623

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
	Total OECD	1990		303.3	14.4	na										1.8623	
		1995		228.8	10.9	na										1.8623	
		2000		216.5	10.3	na					Methane emissions rates					1.8623	
		2005	*coal 2004*	216.9	10.3	na					combined mines		as proportion of product combustion			1.8623	
											kg CH4/tonne coal		kg CH4/t CO2	kg CO2-eq/t CO2			
	EPA, Scheehle 2002	non-OECD		Gg CH4	million tonnes CH4	million tons	million tonnes							aka percent * 10		1.8623	
	China	1990		8,775	8.78	1,190.4	1,079.9				8.126		4.36	91.63	35	1.8623	
		1995		10,373	10.37	1,537.0	1,394.3				7.439		3.99	83.89	36	1.8623	
		2000		8,180	8.18	1,314.4	1,192.4				6.860		3.68	77.35	37	1.8623	
		2005	*coal 2004*	9,438	9.44	*2,156.4*	1,956.3				4.825		2.59	54.40	38	1.8623	
	India	1990		330	0.33	247.6	224.6				1.469		0.79	16.57	39	1.8623	
		1995		421	0.42	320.6	290.8				1.448		0.78	16.32	40	1.8623	
		2000		464	0.46	370.0	335.7				1.382		0.74	15.59	41	1.8623	
		2005	*coal 2004*	680	0.68	*443.7*	402.5				1.689		0.91	19.05	42	1.8623	
	South Africa	1990		320	0.32	193.2	175.3				1.826		0.98	20.59	43	1.8623	
		1995		317	0.32	227.3	206.2				1.537		0.83	17.33	44	1.8623	
		2000		337	0.34	248.9	225.8				1.492		0.80	16.83	45	1.8623	
		2005	*coal 2004*	353	0.35	*267.7*	242.8				1.454		0.78	16.39	46	1.8623	
	World Total	1990		27,129	27.13	5,347.5	4,851.3				5.592		3.00	63.06	47	1.8623	
		1995		24,731	24.73	5,095.8	4,622.9				5.350		2.87	60.32	48	1.8623	
		2000		21,715	21.72	4,935.0	4,477.0				4.850		2.60	54.69	49	1.8623	
		2005	*coal 2004*	23,449	23.45	6,078.6	5,514.4				4.252		2.28	47.95	50	1.8623	
																1.8623	
										Total	300.98		161.614	3,393.90		1.8623	
										Average of above	6.02		3.232	67.88			
	Table 13				CH4 emissions	Coal production					Methane emissions rates					CDIAC 2000 EF	
					million tonnes CH4	million tons	million tonnes				combined mines		as proportion of product combustion			tCO2/t coal	
	World estimates, in Kirchgessner et al, 2000				Tg CH4		Mt				kg CH4/t coal		kg CH4/t CO2	kg CO2e/t CO2		1.8623	
	Kirchgessner, 1993	1989	World		45.6	5,310.1	4,817.3			1989	9.466		5.083	106.74	51	1.8623	
	CIAB, 1994	1990	World		26.0	5,347.5	4,851.3			1990	5.359		2.878	60.43	52	1.8623	
	Fung et al, 1991	circa 1985	World		39.0	4,887.2	4,433.6			circa 1985	8.796		4.723	99.19	53	1.8623	
	Boyer et al, 1990	1987	World		53.5	5,115.9	4,641.1			1987	11.527		6.190	129.99	54	1.8623	
	Cicerone & Oremland,	circa 1985	World		35.0	4,887.2	4,433.6			circa 1985	7.894		4.239	89.02	55	1.8623	
	Crutzen, 1987	circa 1985	World		37.0	4,887.2	4,433.6			circa 1985	8.345		4.481	94.10	56	1.8623	
										Average	8.565		4.599	96.578			
				kg CH4/tonne coal													
	Table 14										Methane emissions rates						
					CH4 emissions	Coal production		CMS estimates			combined mines		as proportion of product combustion				
	Stern & Kaufmann (CDIAC), 1996				Tg CH4	MtC	MtCO2	million t coal			kg CH4/t coal		kg CH4/t CO2	kg CO2e/t CO2			
	Dataset	1860	World		8.5	91	333	179		1860	47.288		25.392	533.23	57	1.8623	
		1880	World		5.2	233	854	458		1880	11.358		6.099	128.08	58	1.8623	
		1900	World		11.5	515	1,887	1,013		1900	11.321		6.079	127.66	59	1.8623	
		1920	World		19.3	843	3,089	1,659		1920	11.620		6.239	131.03	60	1.8623	
		1940	World		22.3	1,017	3,726	2,001		1940	11.161		5.993	125.86	61	1.8623	
		1960	World		30.3	1,410	5,167	2,774		1960	10.913		5.860	123.06	62	1.8623	
		1980	World		38.8	1,947	7,134	3,831		1980	10.134		5.442	114.27	63	1.8623	
		2000	World		43.8	2,370	8,684	4,663		2000	9.387		5.041	105.85	64	1.8623	
		2010	World		63.6	3,807	13,950	7,491		2010	8.490		4.559	95.73	65	1.8623	
	Total	1860-2010	World		3,534.4	173,414	635,420	341,197		Ave 1860-2010	10.359		5.562	116.81	66	1.8623	
						CDIAC Coal Prodn C data 1860-2010											
			Simple average of world estimates reported in Kirchgessner et al and Stern & Kaufmann								9.46		5.211	106.69	67		
															68		

Average global coal mining methane rates

Stern & Kaufmann (1998)
US Environmental Protection Agency (2011) Draft: Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990 - 2030.

Table 15

Stern & Kaufmann on global coal mining methane emissions

CDIAC data from Stern & Kaufmann (1998)
See CMS file CDIAC Global 1751-2010.xls for details

	Total carbon coal production 1860-2010	Total methane from coal mining 1860-2010	Weighted average 1860-2010	Weighted average 1860-2010	Methane per tonne of coal produced	Methane equivalent of coal CO2	
	MtC	Tg CH4 (MtCH4)	kg CH4/tC	kgCH4/tCO2	kgCH4/t coal	kgCO2e/tCO2	% adder for methane
	CDIAC data	Stern & Kaufmann	calculated	calculated	average thermal coal	SAR 21 * cell H168	
		1995-2010 extrapolated					
Total methane 1860-2010 and average CH4 rate	173,414	3,534	20.38	5.562	11.84	116.81	11.68%
	MtC	Tg CH4 (MtCH4)	kg CH4/tC	kgCH4/tCO2	kgCH4/t coal	kgCO2e/tCO2	% adder for methane
Total methane in 2010 and CH4 rate	3,807	63.59	16.70	4.56	9.70	95.73	9.57%
	linked to CDIAC		linked to Stern & Kaufmann				

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Table 16

EPA data and projections on global coal mining methane emissions

US Environmental Protection Agency (2011) Draft: Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990 - 2030,

		World coal prod	Coal emissions	Coal mining CH4	Coal mining CH4	CH4 rate	CH4 rate	CH4 rate
		million tonnes	MtCO2	MtCO2e	MtCH4	kg CH4/t coal	t CH4/t coal	kg CH4/t CO2
		EIA	CDIAC	EPA 2011 Table 3-2	at SAR 21xCO2	calculated	calculated	calculated
		"Internat'l Energy Statistic	CDIAC MtCO2 from coal					
	1980	3,794	7,134					
data in "Total 1990-2010"	1990	4,850	8,864	511.54	24.36	5.02	0.0050	2.748
data in "Total 1990-2010"	1995	4,605	8,963	444.51	21.17	4.60	0.0046	2.362
data in "Total 1990-2010"	2000	4,440	8,684	392.94	18.71	4.21	0.0042	2.155
data in "Total 1990-2010"	2005	5,945	11,586	515.28	24.54	4.13	0.0041	2.118
data in "Total 1990-2010"	2010	7,364	13,950	583.82	27.80	3.78	0.0038	1.993
	2015			628.55	29.93			
	2020			673.56	32.07			
	2025			730.90	34.80			
	2030			790.22	37.63			
	2035			855.62	40.74			
	Total 1990-2010	27,205	52,047	2,448	117	21.7	0.02	11.4
				Weighted average 1990-2010		4.2851		2.240
				Average 1990-2010		4.3470	0.0043	2.275

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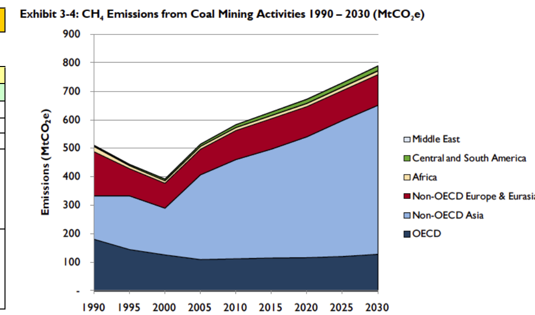
excludes closed mines
EPA 2011, page 3-7



EPA (2011), page 3-7.

Table 17

Comparing global coal mining methane emissions under four scenarios

	MtCO2	Methane Tg CH4	Methane MtCO2e	kg CH4/tC	kgCH4/tCO2	Tg CO2e (MtCO2e)	% adder for methane
Global emissions 2010 if ave. of Stern & Kaufmann and EPA (2011)	13,950	54.42	1,143	14.29	3.901	1,143	8.19%
Global emissions 2010 from Stern & Kaufmann (extrapolated)	13,950	63.59	1,335	16.70	4.559	1,335	9.57%
Global emissions 2010 from EPA (2011)	13,950	27.80	584	7.30	1.993	584	4.18%
Global emissions 2010 from EPA (2011) using average 1990-2010	13,950	31.25	656	8.21	2.240	656	4.70%

Table 18

Pre-IPCC Tier 1 Coal methane rates

		kgCH4/tCO2	kg CH4/t coal
Stern & Kaufmann	(see Table 15)	5.562	11.84
EPA (2011)	(see Table 16)	2.240	4.29
Average		3.901	8.063
Shifted to IPCC Tier 1 factors, Dec12		Source for Table 9	Source for Table 9

Table 3-2: Total CH_4 Emissions from Coal Mining Activities ($MtCO_2e$)

Gas	1990	1995	2000	2005	2010	2015	2020	2025	2030
Total CH_4	511.5	444.5	392.9	515.3	583.8	628.6	673.6	730.9	790.2

US Environmental Protection Agency (2011) Global Anthropogenic Non-CO2 Greenhouse Gas Emissions 1990-2030, Climate Change Division, EPA 430-D-11-003, Aug11, page 3-7

EPA data and on U.S. coal mining methane emissions

Table 19

EPA data on underground (UG) coal mining and associated methane emissions

linked to SumCoal.xls

UG = underground

GcCH4 to MtCH4	US coal (UG)	US coal CO2 (UG)	CH4, UG mining	CH4, abandoned mines	Total CH4 (UG)	CH4 rate	CH4 rate
	million tonnes	MtCO2	MtCH4	MtCH4	MtCH4	kg CH4/tonne mined	kg CH4/tCO2
	EPA 2012 Table 3-30	calculated	EPA 2012 Table 3-29	EPA 2012 Table 3-33	summed	calculated	calculated
	"Internat'l Energy Statistic	(bituminous EF)	*includes post-mining	all from UG mines			
1990	384	937	3.336	0.288	3.624	9.43	3.868
2005	334	815	1.969	0.264	2.233	6.68	2.738
2006	326	794	1.992	0.261	2.253	6.92	2.836
2007	319	778	1.988	0.254	2.242	7.02	2.880
2008	324	790	2.394	0.253	2.647	8.17	3.351
2009	301	735	2.627	0.244	2.871	9.53	3.908
2010	306	746	2.729	0.237	2.966	9.70	3.977
Total 1990-2010	2,295	5,596	17.0	1.8	18.8	57.4	23.6

Weighted average US 1990-2010	8.209	3.366

Table 20

EPA data on surface coal mining and associated methane emissions

	US coal (surface)	US coal CO2 (surface)	Emissions, surface	CH4 rate	CH4 rate
	million tonnes	MtCO2	MtCH4	kg CH4/tonne mined	kg CH4/tCO2
	EPA 2012 Table 3-30	calculated	EPA 2012 Table 3-29	calculated	calculated
		(sub-bituminous EF)	*includes post-mining		
1990	547	992	0.667	1.22	0.672
2005	691	1,254	0.736	1.06	0.587
2006	728	1,322	0.777	1.07	0.588
2007	720	1,306	0.766	1.06	0.586
2008	738	1,339	0.791	1.07	0.591
2009	671	1,218	0.714	1.06	0.586
2010	694	1,259	0.728	1.05	0.578
Total 1990-2010	4,790	8,689	5.2	7.6	4.2

Weighted average US 1990-2010	1.081	0.596

Table 21

EPA data on surface & underground coal mining and associated methane emissions

	US coal (total)	US coal CO2 (total)	Emissions, total	CH4 rate	CH4 rate
	million tonnes	MtCO2	MtCH4	kg CH4/tonne mined	kg CH4/tCO2
	summed	summed	EPA 2012 Table 3-29	calculated	calculated
1990	931	1,929	4.291	4.61	2.224
2005	1,026	2,070	2.969	2.89	1.434
2006	1,054	2,116	3.029	2.87	1.432
2007	1,039	2,084	3.008	2.89	1.443
2008	1,062	2,128	3.438	3.24	1.615
2009	973	1,953	3.585	3.69	1.836
2010	1,000	2,004	3.694	3.70	1.843
Total 1990-2010	7,084	14,285	24.0	23.9	11.8

Weighted average US 1990-2010	3.390	1.681

1 million tonnes coal (ave thermal):	2.1289	MtCO2	(CMS worksheet on coal emissions)
1 million tonnes coal (bituminous):	2.4386	MtCO2	(CMS worksheet on coal emissions)
1 million tonnes coal (sub-bituminous):	1.8141	MtCO2	(CMS worksheet on coal emissions)

linked to SumCoal.xls

Table 3-30: Coal Production (Thousand Metric Tons)

Year	Underground	Surface	Total
1990	384,244	546,808	931,052
2005	334,398	691,448	1,025,846
2006	325,697	728,447	1,054,144
2007	319,139	720,023	1,039,162
2008	323,932	737,832	1,061,764
2009	301,241	671,475	972,716
2010	305,862	693,732	999,594

EPA (2012) U.S draft inventory 2010, page 3-41.

203.7 72

Table 3-28: CH_4 Emissions from Coal Mining (Tg CO_2 Eq.)

Activity	1990	2005	2006	2007	2008	2009	2010
UG Mining	62.3	34.9	34.9	35.7	44.9	49.6	51.6
Liberated	67.9	50.2	50.2	50.9	60.5	66.1	71.4
Recovered & Used	(5.6)	(15.2)	(18.8)	(15.2)	(16.3)	(16.6)	(19.6)
Surface Mining	12.0	13.3	14.0	13.8	14.3	12.9	13.1
Post-Mining (UG)	7.7	6.4	6.3	6.1	6.1	5.6	5.7
Post-Mining (Surface)	2.0	2.2	2.3	2.2	2.3	2.1	2.1
Total	**84.1**	**56.8**	**56.8**	**57.8**	**66.9**	**70.1**	**72.6**

Note: Totals may not sum due to independent rounding. Parentheses indicate negative values.

Table 3-29: CH_4 Emissions from Coal Mining (Gg)

Activity	1990	2005	2006	2007	2008	2009	2010
UG Mining	2,968	1,663	1,693	1,698	2,102	2,360	2,459
Liberated	3,234	2,389	2,588	2,422	2,881	3,149	3,402
Recovered & Used	(266)	(726)	(895)	(724)	(779)	(789)	(943)
Surface Mining	573.6	633.1	668.0	658.9	680.5	614.2	626.2
Post-Mining (UG)	368.3	305.9	298.5	289.6	292.0	266.7	270.2
Post-Mining (Surface)	93.2	102.9	108.5	107.1	110.6	99.8	101.8
Total	**4,003**	**2,705**	**2,768**	**2,754**	**3,186**	**3,340**	**3,458**

Note: Totals may not sum due to independent rounding. Parentheses indicate negative values.

EPA (2012) U.S draft inventory 2010, page 3-40.

Table 3-32: CH_4 Emissions from Abandoned Coal Mines (Tg CO_2 Eq.)

Activity	1990	1995	2000	2005	2006	2007	2008	2009	2010
Abandoned									
Underground Mines	6.0	8.9	8.9	7.0	7.6	8.9	9.0	8.1	7.6
Recovered & Used	+	0.7	1.5	1.5	2.2	3.6	3.7	3.0	2.7
Total	**6.0**	**8.2**	**7.4**	**5.5**	**5.5**	**5.3**	**5.3**	**5.1**	**5.0**

\+ Does not exceed 0.05 Tg CO_2 Eq.
Note: Totals may not sum due to independent rounding.

Table 3-33: CH_4 Emissions from Abandoned Coal Mines (Gg)

Activity	1990	1995	2000	2005	2006	2007	2008	2009	2010
Abandoned									
Underground Mines	288	424	422	334	364	425	429	388	364
Recovered & Used	+	32	72	70	103	172	177	143	126
Total	**288**	**392**	**350**	**264**	**261**	**254**	**253**	**244**	**237**

\+ Does not exceed 0.05 Tg CO_2 Eq.
Note: Totals may not sum due to independent rounding.

EPA (2012) U.S draft inventory 2010, page 3-43.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R

additional data on coal methane

Table 1-2: IPCC Suggested Underground Emissions Factors for Selected Countries

Country	Emissions Factor (m^3/ton)	Emissions Factor[a] (tCO_2eq/ton)
FSU	17.8–22.2	0.25–0.32
United States	11.0–15.3	0.16–0.22
Germany	22.4	0.32
United Kingdom	15.3	0.22
Poland	6.8–12.0	0.10–0.17
Czechoslovakia	23.9	0.34
Australia	15.6	0.22

Source: IPCC, 1996. Adapted from Reference Manual Table 1-54.
FSU = Former Soviet Union.
[a] Conversion factor of 1 m^3 = 0.0143 tCO_2eq = 35.31 ft^3 × 0.00404 tCO_2eq

U.S. EPA (2006) Global Mitigation of Non-CO2 Greenhouse Gases,
EPA Office of Atmospheric Programs and RTI International, 484 pp., page II-5.

Bibler, Carol J., James S Marshall, & Raymond C Pilcher (1998) Status of worldwide coal mine methane emissions and use, International Journal of Coal Geology, volume 35:283–310, Feb98.
Abstrac: "Underground coal mines worldwide liberate an estimated 29–41x10^9 m3 of methane annually, of which less than 2.3 x109 m3 are used as fuel."

Table 1-3: Historical Baseline Emissions for Coal Mine CH_4 for Selected Countries ($MtCO_2eq$)

Country	1990	1995	2000
China	126.1	149.1	117.6
United States	81.9	65.8	56.2
India	10.9	13.7	15.8
Australia	15.8	17.5	19.6
Russian Federation	60.9	36.8	29.0
Ukraine	55.3	30.1	28.3
North Korea	25.3	27.2	26.9
Poland	16.8	15.6	11.9
South Africa	6.7	6.7	7.1
United Kingdom	18.3	12.6	7.0
Germany	25.8	17.6	10.2
Kazakhstan	24.9	17.2	10.0
Colombia	1.9	2.0	3.0
Mexico	1.5	1.8	2.1
Czech Republic	7.6	5.8	5.0
Rest of the world	**37.2**	**32.3**	**27.1**
World Total	**516.7**	**451.5**	**376.9**

Source: USEPA, 2006.

US EPA (2006) Global Mitigation of Non-CO2 Greenhouse Gases, Jun06, page II-5

Table 1-4: Projected Baseline Emissions for Coal Mine CH_4 for Selected Countries ($MtCO_2eq$)

Country	2005	2010	2015	2020
China	135.7	153.8	171.8	189.9
United States	55.3	51.1	46.4	46.4
India	19.5	23.1	28.4	33.6
Australia	21.8	26.4	28.2	29.7
Russian Federation	26.3	27.5	26.9	26.3
Ukraine	26.3	24.5	23.8	23.2
North Korea	25.6	24.3	23.1	21.9
Poland	11.3	10.8	10.3	9.8
South Africa	7.4	7.2	7.1	7.4
United Kingdom	6.7	6.6	6.4	6.2
Germany	8.4	7.7	7.1	5.9
Kazakhstan	6.7	6.4	6.1	5.8
Colombia	3.4	4.0	4.7	5.5
Mexico	2.5	2.8	3.3	3.7
Czech Republic	4.8	3.9	3.1	3.0
Rest of the world	**26.5**	**27.5**	**28.9**	**31.1**
World Total	**388.1**	**407.6**	**425.6**	**449.5**

Source: USEPA, 2006.

US EPA (2006) Global Mitigation of Non-CO2 Greenhouse Gases, Jun06, page II-6.

TABLE 2

ESTIMATE OF GLOBAL METHANE EMISSIONS FROM COAL MINING (1990)

Country	Coal Production (Mt)			CH_4 Emissions (Tg)	
	Underground	Surface	Total	Low	High
China	1,024	43	1,066	9.5	16.6
United States	385	548	934	3.6	5.7
Former USSR	393	309	701	4.8	6.0
Germany	77	359	436	1.0	1.2
India	109	129	238	0.4	0.4
Poland	154	58	212	0.6	1.5
Australia	52	154	206	0.5	0.8
South Africa	112	63	175	0.8	2.3
Czechoslovakia*	22	85	107	0.3	0.5
United Kingdom	75	14	89	0.6	0.9
Subtotal (Top 10)	2,043	1,762	4,164	22.1	35.9
World Total			4,740	24.4	39.6

Source: USEPA (1994).

IPCC (1996) Guidelines: CH4 Emissions: Coal Mining and Handling, page 130.
by William Irving (US EPA) and Oleg Tailakov (Russia Coalbed Methane Center)
Note: the IPCC(2006) Revised Guidelines does not estiamte global emissions

Table A- 119: Underground Coal Mining CH_4 Emissions (Billion Cubic Feet)

Activity	1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Ventilation Output	112	100	90	96	94	92	87	84	79	76	83	75	79	81	100	114	117
Adjustment Factor for Mine Data*	97.8%	91.4%	91.4%	100.0%	97.8%	97.8%	97.8%	97.8%	97.8%	97.8%	97.8%	97.8%	97.8%	100.0%	99.0%	99.0%	99%
Adjusted Ventilation Output	114	109	99	96	96	94	89	86	80	77	84	77	80	81	101	115	118
Degasification System Liberated	54	36	52	43	49	40	45	49	51	50	45	48	54	45	49	49	58
Total Underground Liberated	168	146	150	139	146	134	134	135	131	127	130	124	134	126	150	163	177
Recovered & Used	(14)	(30)	(37)	(28)	(35)	(31)	(37)	(41)	(43)	(38)	(40)	(38)	(46)	(38)	(40)	(41)	(49)
Total	**154**	**116**	**113**	**111**	**110**	**103**	**98**	**95**	**88**	**89**	**90**	**86**	**88**	**88**	**109**	**123**	**128**

* Refer to .
Note: Totals may not sum due to independent rounding.

Table A- 120: Total Coal Mining CH_4 Emissions (Billion Cubic Feet)

Activity	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Underground Mining	154	150	145	120	117	116	113	111	110	103	98	95	88	89	90	86	88	88	109	123	128
Surface Mining	30	28	28	28	29	28	29	30	31	31	30	33	32	31	32	33	35	34	35	32	33
Post-Mining (Underground)	19	18	18	16	17	17	18	18	18	17	17	17	16	16	16	16	15	15	15	14	14
Post-Mining (Surface)	5	5	5	4	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	5	5
Total	**208**	**201**	**195**	**167**	**168**	**166**	**165**	**164**	**165**	**156**	**149**	**149**	**140**	**141**	**144**	**140**	**144**	**143**	**165**	**173**	**180**

Note: Totals may not sum due to independent rounding.

EPA (2012) Draft Inventory of U.S. Emissions and Sinks 2010, Annex 3: Methodological Descriptions for Additional Source or Sink Categories,
Table A-120: Total Coal Mining CH4 Emissions (Billion Cubic Feet)

additional data on coal methane

Table 5-20. Average U.S. Coal Mining CH_4 Emission Factors

Activity	Emission Factor [a], Original Units: scf CH_4/ short ton coal			Emission Factor, Converted Units: tonne CH_4/ short ton coal			tonne CH_4/ tonne coal		
	2005	2006	2007	2005	2006	2007	2005	2006	2007
Underground Mining (Ventilation and Degasification)	241	248	242	0.00463	0.00476	0.00463	0.00511	0.00524	0.00511
Underground Post-Mining (coal handling)	43.4	41.8	42.6	0.000833	0.000801	0.000818	0.000918	0.000883	0.000902
Surface Mining	43.3	43.6	42.8	0.000830	0.000836	0.000822	0.000915	0.000922	0.000906
Surface Post-Mining (coal handling)	6.56	7.47	7.56	0.000126	0.000143	0.000145	0.000139	0.000158	0.000160

Footnotes and Sources:
[a] Derived from data presented in: U.S. Environmental Protection Agency (EPA). *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007, Annexes*, April 15, 2009. See derivation in Appendix B.

American Petroleum Institute (2009) Compendium of Greenhouse Gas emissions Methodologies for the Oil and Gas Industry, Aug09, 807 pp.
Table 5-20, page 5-83

Table 5-21. Australian Coal Mining CH_4 Emission Factors

State	tonnes CO_2e/ tonne run-of-mine coal extracted [a]	tonnes CH_4/ tonne run-of-mine coal extracted
Open Cut Coal Extraction, by State		
New South Wales	0.045	0.945
Victoria	0.0007	0.0147
Queensland	0.017	0.357
Western Australia	0.017	0.357
South Australia	0.0007	0.0147
Tasmania	0.014	0.294
Coal Extraction, by Mine Type		
Gassy Mine	0.305	6.405
Non-gassy mine	0.008	0.168
Post-Mining		
Gassy Mine	0.014	0.294

Footnote and Source:
[a] Australian Government, Department of Climate Change, *National Greenhouse Accounts (NGA) Factors*, Section 2.4.1, November 2008. Original units are tonnes CO_2^{-eq}/tonne run-of-mine coal.

American Petroleum Institute (2009) Compendium of Greenhouse Gas emissions Methodologies for the Oil and Gas Industry, Aug09, 807
Table 5-21, page 5-84.
Note: Column headers appear to be reversed, at CH4 = 21xCO2.

COAL MINE METHANE IN RUSSIA: Capturing the Safety and Environmental Benefits – © OECD/IEA 2009

Table 4: Coal production and estimated average methane releases during 2003 at potentially productive mines in the Kuznetskiy and Pechorskiy basins

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Mine	Average daily production of coal, t/day	Volumes of gas released per minute, including captured CH_4, m^3/min: CH_4	CO_2	Volumes of gas released per tonne of coal produced, m^3/t: CH_4	CO_2	Average output of methane drainage vacuum pumps, m^3/min	Mine rating by methane hazard[16]
Siberian Coal Energy Company (SUEK) *(Kuznetskiy basin)*							
Kirova	9 225	99.0	20.8	18.6	3.3	64.8	Super hazardous
7 November	6 755	31.9	25.5	15.7	15.9	6.6	Super hazardous
Oktiabrskaya	5 200	54.7	21.5	15.2	6.0	40.9	Super hazardous
Polysayevskaya	4 717	79.3	13.0	31.4	6.5	40.9	Super hazardous
Komsomolets	4 363	88.1	17.4	29.1	5.9	61.9	Super hazardous
Yuzhkuzbassugol *(Kuznetskiy basin)*							
Yesaulskaya	12 531	165.4	30.5	20.6	3.9	1.1	Super hazardous
Yubileynaya	5 569	59.5	–	28.1	–	0.2	Hazardous with risk of sudden outbursts
Ulianovskaya	5 964	16.7	–	4.1	–	–	Category 3
Abashevskaya	6 148	133.4	–	31.2	–	61.7	Category 3
Alardinskaya	3 192	72.1	18.9	32.6	8.5	4.9	Super hazardous
Gramoteinskaya	4 947	10.9	8.1	3.1	2.1	2.2	Category 3
Osinnikovskaya	3 110	84.3	34.2	39.0	15.7	0.2	Hazardous with risk of sudden outbursts
Tayzhina	2 702	51.3	8.9	28.7	5.0	11.3	Hazardous with risk of sudden outbursts
Tomskaya	1 030	30.3	14.8	41.6	20.3	0.7	Hazardous with risk of sudden outbursts
Kusheyakovskaya	3 075	10.2	–	3.4	–	–	Super hazardous
Tomusinskaya 5-6	3 236	35.9	11.7	16.0	5.2	–	Super hazardous

[16] Coal mines in Russia are classified according to their relative methane content and nature of risks. There are five mine categories: Category 1 with methane content up to 5 m^3 per tonne (m^3/t) of daily coal production; Category 2: 5-10 m^3/t; Category 3: 10-15 m^3/t; Super-hazardous: over 15 m^3/t; and a fifth category for mines where coal seams with possible outbursts of coal, gas and rock are mined, "Hazardous with risk of sudden outbursts".

COAL MINE METHANE IN RUSSIA: Capturing the Safety and Environmental Benefits – © OECD/IEA 2009

Mine	Average daily production of coal, t/day	Volumes of gas released per minute, including captured CH_4, m^3/min: CH_4	CO_2	Volumes of gas released per tonne of coal produced, m^3/t: CH_4	CO_2	Average output of methane drainage vacuum pumps, m^3/min	Mine rating by methane hazard[16]
Sibir-Ugol *(Kuznetskiy basin)*							
Chertinskaya	1 716	69.9	–	58.6	–	27.1	Hazardous with risk of sudden outbursts
OAO "KuzbassUgol" Berezovskaya	3 111	12.0	9.1	19.1	15.0	–	Hazardous with risk of sudden outbursts
Pervomayskaya	2 547	19.3	6.9	21.8	10.5	–	Hazardous with risk of sudden outbursts
Uzhnii Kuzbass *(Kuznetskiy basin)*							
V.I. Lenin	2 748	45.0	–	26.5	–	13.0	Hazardous with risk of sudden outbursts
Usinskaya	1 427	28.8	8.5	28.6	8.5	3.2	Hazardous with risk of sudden outbursts
OAO "Raspadskaya mine"	15 100	120.8	–	31.0	–	0.4	Super hazardous
Vorkutaugol *(Pechorskiy basin)*							
Severnaya	6 096	153.9	–	36.4	–	103.0	Hazardous with risk of sudden outbursts
Vorkutinskaya	2 114	142,8	–	97,3	–	86,3	Hazardous with risk of sudden outbursts
Komsomolskaya	3 176	126.2	–	57.2	–	54.6	Hazardous with risk of sudden outbursts
Zapoliarnaya	2 812	931	–	47.7	–	23.3	Hazardous with risk of sudden outbursts
Ayach-Yata	2 360	115.0	–	70.2	–	38.6	Super hazardous
Vorgashorskaya	12 200	70.5	–	13.0	–	10.9	Super hazardous

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Source: mine rating data collected annually by regional RosTechNadzor offices (Ruban and Zabourdyaev, 2008).

International Energy Agency (2009) Coal Mine Methane in Russia: Capturing the safety and environmental benefits, 66 pp.

Cell: C21
Comment: Rick Heede:
Stern & Kaufmann estimate coal-mining methane emissions from 1860 through 1994 in Tg CH4 per year. CMS extrapolates methane emissions from 1995-2010 by applying a methane rate per tonne of carbon emitted per year (using CDIAC data) but decreasing by one percent per year 1995-2010. This lowers the rate from 19.62 kg CH4 per tC in 1994 to 16.70 kg CH4 per tC in 2010.
Stern, David I., & Robert K. Kaufmann (1998) Annual Estimates of Global Anthropogenic Methane Emissions: 1860-1994, U.S. DOE, Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center, 4 pp., http://cdiac.esd.ornl.gov/trends/meth/ch4.htm

Cell: C26
Comment: Rick Heede:
IPCC 2006 Guidelines, vol. 2, chapter 4: Fugitive emissions; Surface mining: fugitive methane, page 4.18.

Cell: C59
Comment: Rick Heede:
World Coal Institute (2005) The Coal Resources: A Comprehensive Overview of Coal, London, 44 pp., www.worldcoal.org/resources/wca-publications/

Cell: J137
Comment: Rick Heede:
CMS, 23July2012:
Data for underground coal seams in the Appalachian Basin (USA) suggests CO2 content ranging from 0.5 to 10 percent in coal bed methane studies. As a thought experiment, let's assume an average of 4 percent CO2 content in gas emissions vented from underground coal mining. The United States underground production totaled 305.86 million tonnes (Mt), and 693.73 Mt from open cast mines, 30.6 percent of the 999.59 Mt total in 2010. Methane liberated from underground mines (including post-mining of 0.27 MtCH4) totaled 3.672 MtCH4, and equivalent to 77.1 MtCO2e; thus a methane rate (when divided by UG production) of 9.70 kgCH4/tonne for UG mining, and equivalent to 203.7 kg CO2e/t. Next we dilute methane and CO2 from vented gases by total U.S. coal production, since surface mines have much lower gas content, most of the gases already having migrated, we can broadly estimate that 203.7 kg CO2e/t * 30.6 percent equals 62.3 kg CO2e/t. If we assume 4 percent CO2 content in liberated mine gas - most of which is directly vented (not flared) along with the methane, or captured and used - then the average CO2 rate is 2.4933 kg CO2/tonne coal mined. Multiply this by 2010 global production by Carbon Major entities of 5,692 million tonnes and we estimate global vented CO2 totaling 14.2 MtCO2 (global production [EIA data] of 7,364 t would yield ~18.4 MtCO2 globally vented). The rate per unit of coal-emissions is quite small: the emission factor for coal combustion averaged over all Carbon Major coal producers is 2,025 kg CO2/tonne coal, thus 2.493 kg CO2/ 2,025 kg CO2 equals 0.123 percent, or 1.23 kg CO2/tCO2 from coal combustion.
Sources: Lyons, Paul C. (1996) Coalbed methane potential in the Appalachian states of Pennsylvania, West Virginia, Maryland, Ohio, Virginia, Kentucky, and Tennessee--An overview, USGS Open-File Report 96-735.Cites CO2 content ranging from 0.5 to 10 percent.
U.S. Environmental Protection Agency (2012) Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2010, 471 pp., Feb12, Table 3-30. See also: U.S. Energy Information Administration (2011) Annual Coal Report, Tables 1 and 3.
U.S. Environmental Protection Agency (2008b) Upgrading Drained Coal Mine Methane to Pipeline Quality: A Report on the Commercial Status of System Suppliers, EPA Publication: EPA-430-R08-004, Jan08, Coalbed Methane Outreach Program, US EPA, www.epa.gov/coalbed/docs/red24.pdf. Table 2. Operating CMM Upgrade Facilities: shows CMM N and CO2 in IL, VA, PA, WV, AL ranging in CO2 1% to 5%.
U.S Dept of Energy (2009) Capture and Use of Coal Mine Ventilation Air Methane, Deborah A. Kosmack, Sep09, U.S. Department of Energy & CONSOL Energy Inc. Table 1. Gas Chromatography Analysis of Gas Samples Taken During Vent Capacity Tests: Methane 40 to 44%, N: 50-53%, CO2: 3.6-4.1%.

Cell: K138
Comment: Rick Heede:
Carbon Majors coal production of 162.7 billion tonnes; * 2.62 kg CO2/tonne = 426.6 MtCO2 excluded from CM analysis.

Cell: B157
Comment: Rick Heede:
Andronova, N. G., & I. L. Karol (1993) "The contribution of USSR sources to global methane emission," Chemosphere, vol. 26(1-4):111-126.

Cell: O166
Comment: Rick Heede:
This table summarizes several sources of methane emissions from coal mines in regions and countries of the world. The focus is on methane. A few figures are offered for CO2 emissions -- chiefly from Australian operators -- even though such CO2 emissions are from diesel fuel and electricity consumption, and (as far as CMS can determine) is typically offsite fuel and electricity. Thus, to avoid double counting of fuels already accounted for elsewhere (eg, in crude oil or coal production data), these CO2 emissions estimates are ignored as ancillary emissions sources. There may be cases in which electricity is generated using coal mined on-site, in which case the presumption would be a reduction in reported coal sales; CMS does not have sufficient data to estimate this true ancillary emissions source.

Note: CMS has, necessarily, used production data typically reported by coal operators as "saleable production" or "sales". Run of mine (ROM) production is typically higher but seldom reported. At Centennial Coal Company's proposed Anvil Hill opencast mine, the company estimates average saleable production equal to 76 percent of ROM production. The disposition of the coal not marketed is unknown, and CMS has no indication that any of this coal is used for on-site generation of electricity. CMS does not account for emissions from diesel fuel or electricity, assumed to be procured from third parties, as explained above.

Cell: Q167
Comment: Rick Heede:
Calculated by CMS in worksheet on "Coal C Coefficients" in this workbook.
CMS re-calculated this factor: CDIAC emissions in 2010 / 2000 coal production (EIA data). The 2010 factor (based on forecast coal production, hence not used): 1.894 tCO2/t coal.

Cell: B175
Comment: Rick Heede:
Coal Industry Advisory Board 1992 estimates of methane emissions from mining activities in ten countries is reported in Thakur et al (1994). CMS reports the CIAB estimate for China below.

Cell: B188
Comment: Rick Heede:
EIA (2006) Emissions of Greenhouse Gases in the United States, 2005, Table 16, p. 39; units in million tonnes CH4. Coal production also from EIA (2006) International Energy Annual 2004, Table 2.5 World Coal Production, 1980-2004.

Note: The methane emissions are net to the atmosphere, and account for 0.76 MtCH4 recovered for energy, and is thus combusted into CO2. In 1990, EIA reports 0.26 MtCH4 recovered for energy. The 2004 datum also includes 0.60 MtCH4 of post-mining emissions (0.55 from underground mines and 0.05 from surface mines).

Cell: B190

Comment: Rick Heede:
Andronova, N. G., & I. L. Karol (1993) “The contribution of USSR sources to global methane emission,” Chemosphere, vol. 26(1-4):111-126.

Cell: B195
Comment: Rick Heede:
Thakur et al (1996) “Global Coalbed Methane Recovery and Use,” Energy Conversion and Mngnt, vol. 37: 789-794.

Cell: B197
Comment: Rick Heede:
EPA (2001) Non-CO2 Greenhouse Gas Emissions from Developed Countries: 1990-2010, Appendix B-3 Methane Emissions from Coal Mining Activities, 1990-2010 (MMTCO2), EPA-430-R-01-007. CK: units in MMTCO2, defined on page 1-1: “million metric tons of carbon dioxide equivalent”. Presumably at 21xCO2; confirmed at page 2-1 (per IPCC 1996).

Cell: D201
Comment: Rick Heede:
All country coal production data from US EIA (2006) International Energy Annual 2004, Table 2.5 World Coal Production, 1980-2004; units in million short tons.

Cell: B227
Comment: Rick Heede:
Scheehle, Elizabeth (2002) Emissions and Projections of Non-CO2 Greenhouse Gases for Developing Countries: 1990-2020, draft, 73 pp., US EPA, (still “out for review”).

Cell: Q249
Comment: Rick Heede:
Calculated Jul12 for 2000: CDIAC coal emissions / 2000 coal production (EIA data); see SumCoal.xls

Cell: D251
Comment: Rick Heede:
Kirchgessner, David A., Stephen Piccot, & Sushma S. Masemore (2000) “An Improved Inventory of Methane Emissions from Coal Mining in the United States,” J. of Air & Waste Management Association, vol. 50:1904-1915; also U.S. Environmental Protection Agency, National Risk Management Research Laboratory, 55 pp. epa.gov/ttn/chief/ap42/ch14/related/mine.pdf

The world methane emissions estimates shown below are from Table 1, p. 38; CMS does not listed earlier global estimates from Koyama (1963), Hitchcock & Wechsler (1972), Ehhalt & Schmidt (1978), and Seiler (1984).

Kirchgessner et al provide improved estimates of U.S. methane emissions from coal operations based on direct measurements of coal types. Since the present purpose is to represent estimates of global methane emissions, CMS quotes at length from this important paper on the methodological differences between the global estimates listed below (Kirchgessner et al, p. 3):

“The estimate produced by the Coal Industry Advisory Board (CIAB) yields a relatively low estimate of 26 million tons because of the low emissions factors used. ... Methodological and other differences among the estimates in Table 1 make direct comparisons difficult. One problem is that the estimates represent different base years with different coal production rates and, presumably, different methane emissions. Some estimates did not include that all the coal produced globally account for hard coal only, excluding brown coals and lignite which contain low quantities of methane. Only the estimates of Boyer et al., CIAB, and Kirchgessner et al. include estimates of post-mining operations, and none address the emissions characteristics of abandoned mines. Perhaps the most important difference to understand is that different emissions factors have been employed by the various researchers and, while it is not always explicit from the published papers, factors used range from 160 to 670 ft3 of methane per ton of coal mined. The lowest emissions factors appear to have been based on the assumption that the amount of methane liberated during mining is limited to the methane originally contained in the mined coal. This is a negatively biased assumption for most underground coal mines, since it is now known that actual emissions are usually several times higher than the emissions associated with the mined coal alone.”

Cell: B252
Comment: Rick Heede:
Kirchgessner, D., S. D. Piccot, & J. D. Winkler (1993) “”Estimate of Global Methane Emissions From Coal Mines,” Chemosphere, vol. 26:453-472.

Cell: B253
Comment: Rick Heede:
Coal Industry Advisory Board (1994) Global Methane and the Coal Industry, Organization for Economic Co-operation and Development, Paris.

Cell: B254
Comment: Rick Heede:
Fung, I., J. John, J. Lerner, E. Matthews, M. Prather, L. P. Steele, & P. J. Fraser (1991) J. Geophys. Res., vol. 96:13033-13065.

Cell: B255
Comment: Rick Heede:
Boyer, C. M., J. R. Kelafant, V. A. Kuuskraa, K. C. Manger, & D. Kruger (1990) Methane Emissions from Coal Mining: Issues and Opportunities for Reduction, U.S. Environmental Protection Agency, Office of Air and Radiation; EPA-400/9-90/008.

Cell: B256
Comment: Rick Heede:
Cicerone, R.J., & R. Oremland (1988) Global Biogeochemichal Cycles, vol. 2:299-327.

Cell: B257
Comment: Rick Heede:
Crutzen, Paul J. (1991) Methane’s sinks and sources, Nature, vol. 350:380-381, 4Apr91.

Cell: C263

Comment: Rick Heede:
Stern, David I., & Robert K. Kaufmann (1998) Annual Estimates of Global Anthropogenic Methane Emissions: 1860-1994, U.S. DOE, Oak Ridge National Laboratory, Carbon Dioxide Information Analysis Center, 2 pp., http://cdiac.esd.ornl.gov/trends/meth/ch4.htm
Note: Stern & Kaufmann's emissions estimates run from 1860-1994, and CMS has extrapolated their trends through 2004 assuming a gradually declining methane emissions rate per tonne of coal mined (in order to account for rising utilization of captured methane, especially in Europe and North America).

Cell: N273
Comment: Rick Heede:
CMS calculation, 9Jan07. Note that CDIAC coal emissions of Carbon is summed for the same years (1860-2004) as the Stern & Kaufmann estimate of coal-mining emissions of methane. In CO2-eq terms, 5.77 kg CH4/tCO2 = 121.2 kg CO2-eq/tCO2, or 12.12 percent.

Cell: G326
Comment: Rick Heede:
"The decrease in coal mining CH4 emissions from 1995 to 2000 is caused primarily by mine closures and a significant reduction in coal production during this time period.2 Between 1998 and 2002, the government of China closed tens of thousands of small mines (Andrews-Speed et al, 2005). While EPA's methodology captures the impact of these closures on overall production, the methodology does not distinguish between mining at large and small mines. It is unclear how emissions intensity may differ at various types of mines, and the extent to which production shifted from small to large mines. Moreover, EPA does not estimate emissions from abandoned mines, so emissions resulting from these closures are not reflected in the estimates. China and India, among other countries, have extensive uncontrolled fires in their coal mining regions which may add to fugitive emissions, but are not included in the estimates (Stracher and Taylor, 2004)."
US EPA (2011) Draft Global Anthropogenic Non-CO2 Greenhouse Gas Emissions: 1990-2030, Offc Atm Programs, Aug11, page 3-7.

Cell: H326
Comment: Rick Heede:
EPA (2011) uses SAR (IPCC, 1996) GWP values; CH4 is 21xCO2; page 1-2.

Cell: Q592
Comment: Rick Heede:

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Cell: Q593
Comment: Rick Heede:

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