CH_4 EMISSIONS: COAL MINING AND HANDLING

ACKNOWLEDGEMENT

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ABSTRACT

The amount of methane (CH_4) released during coal mining depends on a number of factors, the most important of which are coal rank, coal seam depth, and method of mining. Underground coal mining releases more methane than surface or open-pit mining because of the higher gas content of deeper seams. Total national emissions from coal mining, regardless of the selected methodology, should be calculated as the sum of emissions from underground mining, surface mining, post-mining activities, and emissions avoided due to recovery. The *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC Guidelines)* provide two general approaches to estimating CH_4 emissions from coal mining. The first approach, outlined in the Tier 1 and Tier 2 methodology is based on coal production and an emission factor. The second approach, the Tier 3 method, uses mine-specific measurement data from ventilation and degasification systems to develop national estimates for underground mines. For countries with significant underground mining, the Tier 3 method is much more reliable because it takes into account variability in geologic formations and mining practices. The difference between Tier 1 and Tier 2 emissions factors for coal mining is that Tier 2 requires measurement data from underground mines within the country itself.

Generally, for both Tier 1 and Tier 2, the uncertainty in the activity data (coal production) is low compared to the uncertainty in the emission factors. Ventilation data from underground mines are much more accurate, typically being accurate to within 20 percent. Important considerations for completeness include emissions from abandoned mines and from waste piles, although currently no methodologies exist and data are difficult to collect. For reporting of emissions, it is important that countries disaggregate fugitive emissions from coal mining and natural gas systems, and also provide information on the method and emission factors used.

1 INTRODUCTION

1.1 Nature, magnitude, and distribution of source

1.1.1 Overview of emissions from coal mining and handling

Methane (CH_4) is produced during coalification (the process of coal formation). Only a fraction of this remains trapped under pressure in the coal seam and surrounding rock strata. This trapped methane is released during the mining process when the coal seam is fractured. Methane released in this fashion will escape into the mine works, and will eventually escape into the atmosphere.

The amount of CH_4 released during coal mining depends on a number of factors, the most important of which are coal rank, coal seam depth, and method of mining. Coal rank represents the differences in the stages of coal formation and depends on the temperature history of the coal seam. As coal rank increases, the amount of CH_4 produced also increases. Because pressure increases with the depth of the coal seam and the adsorption capacity of coal increases with pressure, deeper coal seams generally contain more methane than shallow seams of the same rank.[1] In addition, over time methane can be released to the atmosphere from near surface coal seams through natural fractures in overburden strata. Coal extraction tends to lead to the release of more methane than was originally trapped within the mined coal seam itself, because the drop in pressure draws in additional gas from surrounding strata. Also, the mining process tends to fracture the surrounding strata including neighbouring seams, particularly where long wall extraction is used.[2]

Underground coal mining releases more methane than surface or open-pit mining because of the higher gas content of deeper seams. Because CH_4 is highly explosive in air concentrations between 5 and 15 percent, mine operators have developed two types of systems for removing methane from the underground mine workings: (i) ventilation systems, and (ii) degasification systems. The purpose of ventilation systems, used extensively in all major coal producing countries, is to reduce CH_4 concentrations to safe levels, usually less than 1 percent. Despite the low CH_4 concentration, the large amount of air flushed through mine ventilation shafts leads to significant annual emissions. At present almost all ventilation air is emitted into the atmosphere. Preliminary studies by USEPA indicate that economic options exist in some situations for the use of vented air.[3]

Drainage or “degasification” systems have been installed at some of the gassiest underground mines in Australia, United States, Russia and other countries. Typically, these systems are employed at mines that need to supplement ventilation systems with additional CH_4 recovery for safety reasons. Degasification systems extract CH_4 from the coal seams in advance of mining, during extraction, and during post-mining, by means of bore holes drilled from surface or horizontally into the seam or surrounding strata. Depending on the quality of the gas, which in some cases can be high, mine operators can use recovered CH_4 for on-site electricity generation or sell it to a local pipeline.

At surface mines, methane escapes from newly exposed coal faces and surfaces, as well as from areas of coal rubble created by blasting operations. Additional CH_4 may come from the overburden, which is broken up during the mining process, and the underlying strata, which may be fractured and distressed due to the removal of the overburden. Emissions per ton of coal are generally much lower from surface mining than from underground mining.

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[1] See discussion of methodologies for further elaboration of correlation between emissions and depth.

[2] Whilst CH_4 in coal is usually assumed to have been produced by coalification, detailed isotopic studies show that CH_4 found in shallower (< 500m) seams is not necessarily consistent with this notion. The isotopic signature is more like that of landfill gas, which is produced by microbial processes such as CO_2 reduction or fermentation. Seams with this type of CH_4 are generally dry, i.e., contain no significant amounts of higher hydrocarbons. Some coal seams, particularly in Australia, but also in France and Poland, have high CO_2 contents. Indeed, the gas in some seams may contain close to 100 percent CO_2, and is thought to have a magmatic origin. High levels of CO_2 are usually restricted to the shallower seams less than 500m depth.

[3] USEPA (1998) *Draft,* Technical Assessment Report: Mitigation of Methane Emissions from Coal Mine Ventilation Air“

Methane emissions also occur during post-mining handling, processing, and transportation. Some CH_4 is released from coal waste piles and abandoned mines. Emissions from these sources are believed to be low because much of the CH_4 would likely be emitted within the mine.

The top ten largest coal producing nations account for over 80 percent of world coal production, and over 90 percent of hard coal production (see Table 1).[4] The top three producers, China, US, and India account for over two-thirds of global hard coal production.

TABLE 1

LEADING PRODUCERS OF COAL (1997)

Producers	Hard Coal (Mt)	Brown Coal (Mt)
China	1,348	*
United States	909	79
India	310	23
South Africa	220	0
Australia	207	58
Russia	157	85
Poland	138	63
Ukraine	71	5
Kazakhstan	70	3
Indonesia	54	0
Rest of the World	290	585
World	3,775	901

* Included in Hard Coal. The majority of Chinese production is hard coal.

Sources: Energy Statistics and Balances of non-OECD Countries; Coal Information.

Global estimates of methane emissions from coal mining show a large variation, in part due to the lack of comprehensive data from all major producing countries. USEPA estimated in 1994 that global emissions from coal mining in 1990 were in the range of 24 - 40 Tg.[5] The large range is a result of the use of global or regional emissions factors as substitutes for country-specific data. Leading emitters, alongside 1990 coal production, are shown in Table 2. Emissions have decreased since 1990 in countries such as Germany, Russia, and UK, because of coal industry restructuring. Increased production in India, China, and Indonesia through the 1990s may lead to higher emissions later in the decade. Annual inventory data from the United States and Australia indicate increased use of coal mine methane, thus avoiding emissions to the atmosphere.

[4] Hard coal produces the highest methane emissions

[5] USEPA (1994) International Anthropogenic Methane: Estimates for 1990.

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).					

2 METHODOLOGICAL ISSUES

2.1 Selection of good practice methods

Total national emissions from coal mining, regardless of the selected methodology, should be calculated using the following general equation:

Total Emissions = Emissions from Underground Mines
+ Emissions from Surface Mines
+ Emissions from Post-Mining Emissions
- Emissions Avoided Due to Recovery

Underground Mining: The *IPCC Guidelines* provide two general approaches to estimating CH_4 emissions from coal mining. The first approach, outlined in the Tier 1 and Tier 2 methodology uses the following basic equation:

EQUATION 1

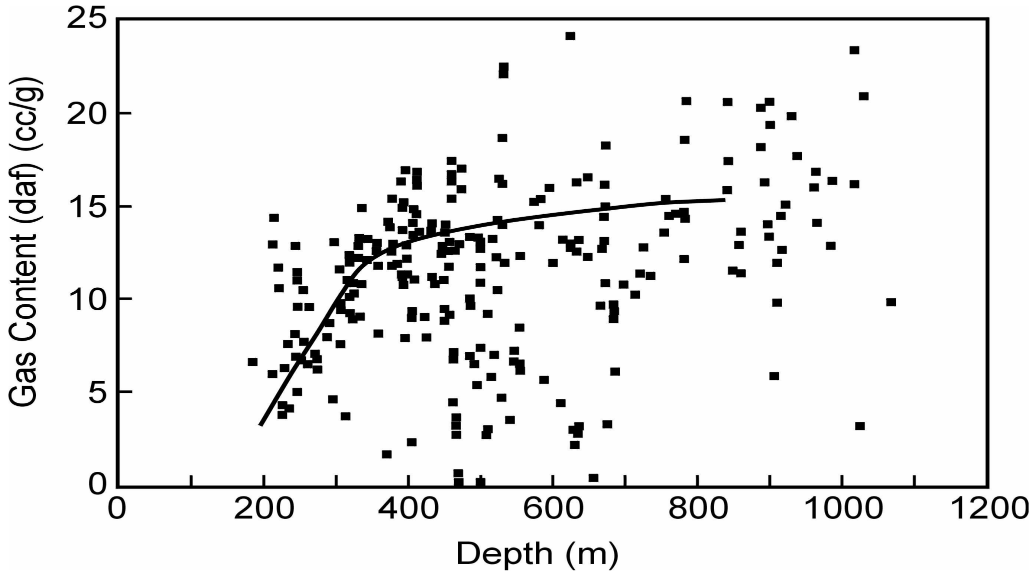
$$\text{Emissions (Gg } CH_4) = \text{Emissions Factor } (m^3\ CH_4 / \text{tonne}) \bullet \text{Tonnes of Coal Produced} \bullet \text{Conversion Factor } (Gg/\ 10^6 m^3)$$

The Tier 1, or “Global Average Method,“ requires the selection of an emissions factor (10-25 m^3/ tonne) within a range specified by IPCC and drawn from the findings of regional studies. This method is to be used when national underground coal production data are available, but more detailed regional data are not. For the Tier 2 method, also known as the “Country or Basin Specific Method,” national experts develop emissions factors unique to a country or coal basin on the basis of at least a limited number of measurement data. These data could be used to develop emission factors through expert judgement or statistical analysis. For both Tiers, the conversion factor is given as 0.67 $Gg/10^6\ m^3$.

The second approach, the Tier 3 method, uses mine-specific measurement data from ventilation and degasification systems to develop national estimates for underground mines. For the minority of mines without data, this method requires assumptions to fill data gaps. The mine-specific method produces the most accurate estimate because it uses actual emissions rather than assumed emission factors.

The assumption that deeper coal seams generally contain more methane than shallow seams of the same rank usually holds true for gas content data from a single bore-hole, but when such data are examined basin-wide, there is a lot of variability as seen in Figure 1. This is one of the compelling reasons why a mine by mine approach (ie Tier 3) is necessary for credible estimates of fugitive emissions to be made. Nevertheless, for mining situations where emission factors have to be used, the rough correlation of gas content with depth can be used as guide for the choice of emission factor.

Figure 1 Variation of gas content with depth across a coal basin



Surface Mining: The IPCC recommends a Tier 1 and Tier 2 method for surface mining, both of which use the same general equation form as described for underground mining. For the Tier 1 Global Average Method, the emission factor range of 0.3 – 2.0 m^3/ tonne reflects a range of literature estimates and incorporates both *in-situ* gas content and migration of CH_4 from surrounding strata. The Tier 2 Country Basin Specific Method separates the emissions factor into a term for the *in-situ* CH_4 content, and a term (usually a multiple or percentage of *in-situ* CH_4 content) that accounts for emissions from surrounding strata:

EQUATION 2

Emissions (Gg CH_4) = [In-Situ Gas Content (m^3 CH_4 / tonne) ● Surface Coal Production (Mt) ● Conversion Factor (Gg/ 10^6m^3)]

+ [Assumed Emissions Factor for Surrounding Strata (m^3 CH_4 / tonne) ● Surface Coal Production (Mt) ● Conversion Factor (Gg/ 10^6m^3)]

Data on in-situ CH_4 content usually come from measuring coal samples from specific basins and mines.

Post-Mining There are few estimates on which to base emissions factors for post-mining emissions. Due to the higher in-situ CH_4 content, post-mining emissions of underground-mined coal are assumed to be higher than surface-mined coal. The Tier 1 Global Average Method recommends an emissions factor range for both surface (0 to 0.2 m^3/tonne) and underground-mined coal (0.4 to 4.0 m^3/tonne), and the Tier 2 Country or Basin Specific Method uses the following equation:

EQUATION 3

Emissions (Gg CH_4) = In-Situ Gas Content (m^3 CH_4 / tonne) ● Underground or Surface Coal Production (Mt) ● Fraction of Gas Released During Post-Mining Activities (%) ● Conversion Factor (Gg/ 10^6m^3)

Emissions Avoided: For all Tiers, the *IPCC Guidelines* account for methane utilization by adjusting the estimate of gross emissions downward by the amount recovered and used. Data on gas utilization is obtained from either the coal industry itself or it must be inferred from information about recovery efficiency, gas sales or end-use data.

2.2 Emissions factors

Tier 1: The IPCC default emissions factor ranges listed in Table 3 are synthesized from a number of country-specific studies, and do not necessarily reflect current conditions in any particular country. As more countries conduct emissions studies, there will be less of a need to choose an emissions factor from these ranges.

TABLE 3

TIER 1 DEFAULT IPCC EMISSIONS FACTORS (M^3 CH_4 / TONNE)

Category	Low	High
Underground Mining	10	25
Surface Mining	0.3	2.0
Post-Mining (Underground)	0.9	4.0
Post-Mining (Surface)	0	0.2

Use of the Tier 1 emissions factors introduces uncertainty. Because of the magnitude of emissions, it is particularly important to choose an underground mining emissions factor that reflects country-specific conditions as closely as possible. The *IPCC Guidelines* cite numerous studies as the basis for underground mining emissions factors. These and other studies of mines or basins whose geological and engineering conditions closely resemble those within the country will provide insight into choosing within the IPCC range. A database of emissions factors, which includes a description of contributing factors such as in-situ content, depth, and permeability, would facilitate this expert judgement.

Tier 2: Underground Mining The difference between Tier 1 and Tier 2 emissions factors for underground mining is that Tier 2 requires measurement data from underground mines within the country itself. Because geologic factors rather than political borders determine emissions, it is advisable to generate emissions factors for each basin within countries that have multiple basins.

The Australian inventory used 1990 CH_4 concentrations, ventilation flow rate, in situ CH_4 content, and coal production rate data provided by a subset of individual mines to develop country-specific emissions coefficients for gassy and non-gassy mines.[6] In Australia, as in the United States and other large coal producing nations, the bulk of emissions come from a relatively small number of gassy mines, and the relationship between the underlying variables and emissions for these mines is qualitatively different from smaller less gassy mines. Statistical regression produced the following equation for gassy mines:

EQUATION 4

$$\text{Emissions}_{1990} = (4.95 \bullet \text{Coal Production} \bullet \text{In-Situ Content}_{1990} + 5.58) \bullet \text{Conversion Factor}$$

Repeating the analysis for the same subset of mines four years later produced a different equation:

EQUATION 5

$$\text{Emissions}_{1994} = (4.01 \bullet \text{Coal Production} \bullet \text{In-Situ Content}_{1994}) \bullet \text{Conversion Factor}$$

That the second equation gives an estimate that is about one-third lower than the first highlights the need for multiple measurements in different years for the same mines, and from as many mines as possible with the same year. Part of the change in the equations is due to actual variability in mining emissions, and the remainder is due to uncertainty in the measurement data. Emissions from a given level of production could change because of factors such as the closure or opening of large gassy mines, mining deeper into the same or neighbouring coal seam, or a change in mining techniques. The Australian inventory takes the average of these two results to come up with a national estimate.

Tier 2: Surface Mining Measurements of actual emissions from surface mining are technically difficult, costly, and generally are not available for inventory preparation. An alternative outlined in Tier 2 is to base the estimate on the *in-situ* gas content of surface coal. *In-situ* gas contents can vary greatly within a country as demonstrated by basin-specific data from the US inventory as shown in Table 4.

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[6] Australian National Greenhouse Gas Inventory. (http://www.greenhouse.gov.au/inventory/natinv/95/95energy/n95_1b1.html)

TABLE 4 US SURFACE COAL IN-SITU CONTENT	
Basin	**Average In-Situ Content (m^3/tonne)**
Northern Appalachia	1.3
Central Appalachia	1.3
Warrior	1.3
Illinois	1.0
S.West/Rockies	0.4
N. Great Plains	0.08
West Interior	0.08
Northwest	0.08
Source: EPA (1993).	

The assumption is that all of the in-situ gas is released during surface mining, although to avoid double counting, this assumption should be modified if countries also assume that a fraction of in-situ CH_4 is released during post-mining activities. To account for the methane that migrates from surrounding strata, the assumed emissions factor should be based on measured variables such as gas content, and qualitative characteristics such as permeability.

Tier 2: Post-mining Tier 2 post-mining emission factors are based on the *in-situ* contents of coal seam. The quality of these emission factors will depend primarily on the quality of the emission factors developed for surface and underground mining.

Tier 3: Underground Mining Coal mine methane is a safety hazard because it is highly explosive in ambient concentrations between 5 and 15 percent. All gassy underground mines must ventilate CH_4 to ensure safe working conditions, and data from these measurements can be used to estimate national emissions. In theory, total national ventilation emissions are equal to the sum of emissions from each mine. There are five general issues associated with using mine-specific ventilation data, however, that should be considered:

- For each mine, periodic sample measurements (usually CH_4 concentration or flow rate) must be used to estimate total emissions over one year. In almost all cases, mines do not currently monitor CH_4 emissions continuously. Instead, the frequency of sampling depends on national and local regulations, and local practices. It may be necessary to take the average of multiple measurements. The greater the variability in ventilation emissions, the more measurements will be needed to complete a representative sample.
- Sampling should be representative of typical mining conditions. If samples are taken when there is a temporary stop in coal production, for example, ventilation estimates are likely to underestimate CH_4 emissions.
- Data may not be available for each mine. In some countries, only data from the gassiest mines are available and the emissions from the remainder must be estimated. Data may also be missing when mine operators report it on a voluntary basis. In most coal basins, however, a small number of gassy mines contribute to a disproportionately large share of total emissions. Figure 1 shows that, in the case of four major coal-producing countries (US, Poland, Australia and Russia) the 10 gassiest mines emit over 60 percent of total emissions.[7] With limited resources, it is recommended that countries focus on obtaining data for the top 10 to 20 emitting mines, and then estimate emissions from less gassy mines, rather than abandon the Tier 3 method for more general emission factors (see Figures 2 and 3.). While it may not be possible to determine which mines are in the top 10-20 percent without original data, a complete survey during one year would allow countries to focus on the high emitting mines in future years. Where this is not possible, periodic surveys of mine operators would enable countries to determine which mines are the gassiest. Such mines typically suffer from more work slowdowns, outbursts, and, in unfortunate cases, methane explosions. Estimating emissions from the less gassy mines without data is relatively straightforward since total emissions from a large number of small sources are less susceptible to yearly fluctuations. If, in a year with

[7] Mine totals include both ventilation emissions and emissions from degasification or drainage systems.

full data, the subset of less gassy mines accounted for 20 percent of total emissions, the same subset will likely account for a similar proportion in future years.[8]

- Data may not be available for each year. If data is available for one year, but not subsequent years, coal production-based emission factors can be back-calculated and applied to production statistics for future years. If the same mines are in operation from year to year, this technique can produce a high quality estimate. If, however, key mines close and others open, the back-calculated emissions factors are less reliable.
- Ventilation air measurements are not possible when CH_4 concentrations are below detectable levels. While it is technically possible to measure minute amounts of CH_4, from a mine safety perspective, it is not necessary to measure CH_4 below approximately 0.1 percent of overall volume. For widely used methanometers, concentrations below 0.1 percent are considered non-detectable. Flushing a large air volume with even small amounts of CH_4 over the course of a year can produce significant emissions. One strategy to account for these emissions is to assume an average methane concentration (a figure below 0.1 percent) and multiply this figure by an average ventilation rate. For example:

EQUATION 6

Non-Detectable CH_4 Emissions = 0.05%CH_4 /Air Volume ● Average Ventilation Flow Rate/Day ● 365 Days

A complete inventory should also account for CH_4 emitted from gassy mines with degasification or drainage systems. The following issues should be resolved when accounting for degasification system emissions:

- Degasification system emissions can occur before, during and after the coal seam has been mined through. In the US, mine operators often drill vertical wells into the coal seam in advance of mining to drain as much CH_4 as possible. Similarly, many countries drill wells into the gob area remove CH_4 after the seam has been mined through. If a country is using actual emissions data from degasification systems, both of these emissions should be accounted for in the year in which the coal was mined. The same conditions apply to the use of gas sales data for estimating emissions from degasification systems.
- Degasification system emissions can be estimated on the basis of recovery efficiency. It is in the interest of mine operators to know the efficiency with which degasification systems remove CH_4 from a coal seam. Emissions can be estimated from the following equation:

EQUATION 7

Total Mine Emissions (m^3) = [Ventilation Emissions (m^3)] / [100% - Efficiency Factor]

When information on degasification efficiency is not available, countries should apply default efficiencies. One option is to apply high, medium, and low efficiencies of 60 percent, 40 percent, and 20 percent.

2.3 Activity data

Tiers 1 and 2: For Tier 1, data on national underground and surface coal production are sufficient for estimating national emissions. This data can be obtained from the appropriate national agency, or from the International Energy Agency. If a country disaggregates emission factors by coal basin or political district, coal production statistics should follow the same breakdown. In cases where a political district contains two or more coal basins and production statistics are available only at the district level, the production data should be allocated to each basin. For both tiers, post-mining emissions requires the same activity data as underground and surface mining.

Tier 3: Coal production data are not used when a country bases the estimate of underground mine emissions on ventilation and degasification system measurements. It may be useful to check the Tier 3 method by comparing it to the emissions estimate based on coal production and emissions factors. This would allow inventory experts to evaluate the relevance of commonly used emissions factors to specific countries. Production data is also necessary when measurement data is not available each year, and the methodology uses emissions factors that have been back-calculated from previously used data.

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[8] This assumes no major changes in the subset of large gassy mines.

Figure 2 Distribution of emissions from US (1997), Poland (1988), Russia (Kuznetsk Coal Basin, 1998) and Australia (1995) underground mines

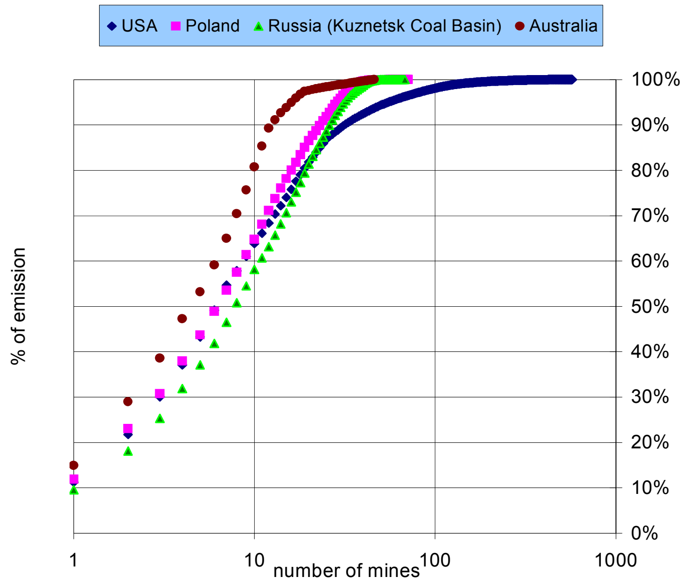
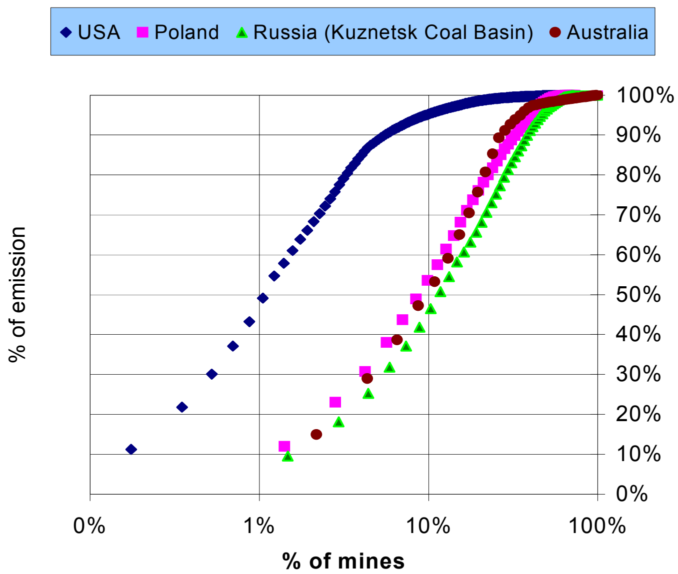


Figure 3 Distribution of emissions from US (1997), Polish (1998), Russia (Kuznetsk Coal Basin, 1998) and Australian (1995) underground mines



2.4 Calculating emissions avoided

Wherever possible, the national emission estimates should take into account the collection and use of CH_4 as fuel.[9] At present, all recovered CH_4 comes from degasification systems, and the calculation of emissions avoided requires much of the same data and techniques as the calculation of emissions. If degasification system data are available, then it should be possible to determine the total amount of gas collected, the amount of gas used for fuel, and any portion vented to the atmosphere. It may be necessary to estimate the amount of methane drained from degasification systems, and then subtract the amount of methane burned from data on gas sales. In this case, it is important to determine whether or not the gas sold was drained from coal seams that are being mined in the current year. A general rule is that *emissions avoided are linked to specific coal seams.* For example:

- If gas is recovered from a degasification system and used as fuel, but the coal seam is never mined due to unforeseen economic or engineering factors, this should not be counted as emissions avoided.
- Similarly, if coal seams are being mined for gas and there is no intention of ever mining the coal itself, this gas use should not be counted as emissions avoided. Fugitive emissions from this process should be accounted for as part of the oil and gas sector calculation.
- Gas recovered in advance of mining should be counted as emissions avoided in the year when the source coal seam is mined through.

Annex 2 shows a sample calculation of emissions avoided from a set of underground mines, using gas sales data. While almost all recovered gas comes from underground coal mines, in the western US and in other countries, CH_4 is being recovered from gassy surface coal seams.

2.5 Uncertainty

Parallel to the IPCC sector-specific workshops on *good practice guidance*, the IPCC is completing a programme of work on emissions inventory uncertainty. This work will result in recommendations to the United Nations Framework Convention on Climate Change (UNFCCC) on approaches to assessing and managing uncertainty. During the IPCC Inventory Experts Group Meeting in Paris (October 1998), technical experts in the uncertainty programme came up with a series of questions to be answered in the sector workshops. Specifically, the sector workshops should provide answers to these questions in the individual source context. The questions are listed in the general background paper.

Generally, for both Tier 1 and Tier 2, the uncertainty in the activity data (coal production) is low compared to the uncertainty in the emission factors. Underground mining emission factors are based on more measurement data than surface mining, and there are very few measurements on which to base emission factors for post-mining activities. Given the large contribution to total emissions from underground mining, and the feasibility of collecting accurate measurement data from these mines, the best way to reduce uncertainty is focus on the Tier 3 method. Below is a description of the major uncertainty issues for the Tier 1, 2 and 3 IPCC methodologies.

Tier 1: Given that the emissions factors for Tier 1 are not based on country-specific data, they do not represent geologic conditions accurately for each country. The emissions factors are highly uncertain as a result.

Tier 2: The primary sources of uncertainty in the Tier 2 emissions factors are the unrepresentative measurement samples, and the natural variability of *in-situ* CH_4 content. Consequently, efforts undertaken to reduce uncertainty should focus first on improving emission factors, or in the case of underground mining, collecting the necessary ventilation data to use a Tier 3 method.

Tier 3: The Australian national inventory estimates that mine ventilation data is accurate to within approximately ± 20 percent. More frequent measurement could reduce this uncertainty. More work needs to be done to assess the accuracy of ventilation system data, but there is more uncertainty associated with estimating the recovery efficiency of degasification systems, and estimating emissions avoided from gas sales for previous years.

[9] Coalbed methane is generally not flared on site because of safety concerns. Should this practice be adopted, countries should subtract flared gas from national emissions totals.

2.6 Completeness

Abandoned coal mines: Emissions from abandoned mines may come from unsealed shafts and from vents installed to prevent the build-up of CH_4 in mines. There is very little information on the number of abandoned mines, and no data are currently available on emissions from these mines. The *IPCC Guidelines* do not suggest a methodology for estimating these emissions, but if a country has data on which to base a measurement, it should do so in a transparent manner.

Waste piles: Coal waste piles are comprised of rock and small amounts of coal that are produced during mining along with marketable coal. There are currently no emission measurements for this source. Emissions are believed to be low, however, because much of the methane would likely be emitted in the mine and the waste rock would have a low gas content compared to the coal being mined.

2.7 Other important issues

Baseline: An emissions baseline is an important component of an inventory program. When a country has sufficient ventilation data for a Tier 3 method during the current year, but this data is not available for the baseline year, the inventory will have to reconcile different data sets.

3 REPORTING AND DOCUMENTATION

A recent report from the UNFCCC Secretariat "Methodological Issues Identified While Processing Second National Communications" (UNFCCC/SBSTA/1998/7) noted that some Parties presented aggregate emission figures for broad IPCC sectors only, such as for *industrial processes* and *fugitive emissions,* and did not disaggregate their emissions on sub-sectors and source categories *as is_requested by the IPCC_Guidelines*. For the purpose of transparency and comparability, it is important to disaggregate fugitive emissions from fossil fuels into coal mining, natural gas, and oil. The processes are quite distinct and, since the calculations must be done separately, this should not impose a burden. In addition, reporting them separately should not reveal any confidential information

Transparency will be improved if all countries report estimates for underground, surface, and post-mining activities separately, and indicate whether they use Tier 1, Tier 2, or Tier 3 methods for each sub-source. It is also important that all information used to estimate emissions be available either directly in national inventories or indirectly by citing other documents. For Tier 1 and Tier 2, countries should report coal production and the emission factors used. Tier 2 calculations should also show how emissions factors were developed. For Tier 3 calculations of emissions from underground mining, countries should report the number of mines with and without data, any assumptions necessary to use the data, the number of mines with degasification systems in place, and the number of mines recovering gas for use as fuel.

3.1 Current IPCC reporting guidelines

The *IPCC Guidelines: Reporting Instructions* are used to guide countries in the preparation and submissions of annual greenhouse gas emissions inventories to the UNFCCC. The Guidelines establish:

- Standard tables, definitions, units, and time intervals for reporting all types of emissions;
- Necessary documentation to enable comparison of national inventories, including worksheets, major assumptions, methodological descriptions, and enough data to allow a third party to reconstruct the inventory from national activity data and assumptions, and
- An uncertainty assessment.

CH_4 emissions from coal mining are reported in sheet 2 of Table 1: Sectoral Report for Energy, which calls for entries under fugitives for emissions from coal mining, solid fuel transformation, and 'other'. Reporting the share of emissions from the different sub-categories – underground mining, surface mining, post-mining activities – would provide significantly more transparency than is requested currently.

3.2 Confidential business information

Coal mine operators may judge degasification system emissions specifications, emissions avoided data, or mining practices to be sensitive. Should this be the case, inventory agencies will need to publish only aggregate data on recovery and emissions avoided, or estimate emissions from publicly available information on gas sales.

4 INVENTORY QUALITY

4.1 Introduction

Inventory quality assurance and quality control (QA/QC) is a process integral to the development of a credible inventory. A well-developed and well-implemented quality assurance programme fosters confidence in the final inventory results regardless of the purpose and goal of the inventory. A successful quality assurance programme requires internal quality control procedures and an unbiased, external review and audit. The internal QC activities are used to ensure accuracy, documentation, and transparency during inventory preparation. The external independent review (QA) process is designed to identify errors that occur in the preparation of emissions inventories, and reduce or eliminate potential inherent bias. Figure 4 outlines the flow of information and processes followed at each step.

Figure 4 Inventory QA/QC process

	Mine Safety Agency
Internal QC:	Ventilation emissions data; degasification data (if applicable); uncertainty assessment
Documentation:	Mine-specific emissions data; QC results; number, frequency, and location of samples
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	GOVERNMENT INVENTORY AGENCY
Review/QA:	Production data, externally developed emissions factors, mine-specific data, gas sales, and calculations
Internal QC:	Emission factor development, emissions calculations, emissions avoided account
Documentation:	Results of compilation and results of QA/QC
Reporting:	Official submission to UNFCCC
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	External Review
External Review:	External audit, stakeholders, peer & public review of inventory results, external verification against other data etc.
Documentation:	Results of external review

4.2 Internal inventory QA/QC systems

4.2.1 Emission factor development

Emissions factors QC

Tier 1 The range of default emissions factors comes from an IPCC assessment of relevant literature. QC procedures include reviewing the national circumstances and documenting the rationale for selecting specific values. Other QC procedures are not required.

Tier 2 QC procedures for the Tier 2 emissions factors involve checking the equations and calculations used to calculate the emissions factor. The Tier 2 emissions factors are based on country or basin-specific information on *in-situ* gas contents and a limited set of emissions measurements for underground mines. Sampling should follow consistent protocols to ensure that conditions are representative and uniform.

Tier 3 Because of safety concerns, each individual mine should already have in place a QA/QC programme for monitoring ventilation emissions. The mine safety agency carries out random sampling checks of these mines and will have additional quality control procedures. The inventory agency should work with mine operators to ensure the quality of data from degasification systems.

Emissions Factors Documentation

Documentation is a crucial component of the review process because it enables reviewers to identify mistakes and suggest improvements. A standardized reporting form is recommended to provide transparent information on the steps taken to calculate the emissions factor or measure emissions. Each step should contain the numbers used in each calculation, including the source of any data collected.

4.2.2 Collection of activity data

Activity Data QC

Tier 1 and Tier 2 - Coal Production Data A country's ministry of energy generally collects annual coal production data or a similar organization focused on the energy sector. The data are generally not collected for greenhouse gas inventories. The personnel that collect data are responsible for reviewing the data collection methods, checking the data to ensure they were collected and aggregated correctly, and cross-checking the data with previous years to ensure the data are reasonable. In addition to a description of weak spots and suggestions for improvement, the basis for the estimates, whether statistical surveys or 'desk estimates,' must be reviewed and described as part of the QC effort.

Activity Data Documentation

Documentation is a crucial component of the review process, because it enables reviewers to identify mistakes and suggest improvements. Among others, the following information is needed for the reviewing/auditing agency:

- A highly detailed description of the methods used to collect the activity data, and
- A discussion of potential areas of bias in the data, including a discussion of whether the animal and feed characteristics are representative of the country.

4.2.3 Inventory agency level activities

Inventory Agency Review (QA) of Activity Data

Before accepting the activity data, the inventory agency should assess its quality. This review involves close cooperation with the personnel responsible for collecting, compiling, and analyzing the data. The assessment should include a review of the detailed methods used to collect the data, including a review of any surveys and interviews performed to collect the data. In addition, the assessment should include a comparison of the activity data with historical data, a discussion of the potential for bias, and recommendations for improvement.

Inventory Agency Review (QA) of Emission Factors

When the inventory agency applies emission factors from the literature, it should review the background data, measurements and assumptions used to come up with these emissions factors. It is particularly important to check for representative sampling, sufficient sampling size, and documented assumptions. This may entail contacting researchers to ask for additional information. Review of ventilation data should follow a procedure similar to the review of coal production data. This review will involve close cooperation with the mine safety agency to determine collection methods and review raw data.

Inventory Agency Review (QA) of Emissions Avoided Data

Emissions avoided data will be based on reports from mine operators, and from gas sales statistics. A review should determine the completeness and accuracy of this data, and its suitability for determining CH_4 use. The magnitude of reported emissions avoided should be consistent with degasification system capacity and coal production for a given year.

Inventory Agency QC on Compiling National Emissions

In addition to a thorough quality assessment of data discussed above, the inventory agency should ensure that the process of aggregating data to develop the national inventory undergoes quality control. This should include, among other things:

- Back-calculating national and regional emission factors from the Tier 3 measurement data (if using Tier 3);
- Ensuring that the emission factors are representative of the country (if using Tiers 1 and 2);
- Ensuring that all mines are included, and
- Comparing with national trends to look for anomalies.

Inventory Agency Documentation on Compiling National Emissions

For the CH_4 emission inventory for coal mining, a QA/QC management plan should address the specific items needed to perform audits and reviews. Examples of the types of information needed for documentation and external audit include:

- A detailed description of the inventory methodology;
- Identification of the input parameters that are needed and how the input parameters are obtained, and
- Frequency of data collection and estimation and results of determinations of accuracy and precision.

4.3 External inventory QA/QC systems

External QA activities include a planned system of review and audit procedures conducted by personnel not actively involved in the inventory development process. The key concept is independent, objective review to assess the effectiveness of the internal QC programme, the quality of the inventory, and to reduce or eliminate any inherent bias in the inventory processes. Several types of external reviews, or audits, may be appropriate for the inventory of CH_4 emissions from coal mining. Reviews should always occur when methods change. If methods do not change, it is recommended that countries review the methods annually, or, if resources are limited, every three to four years. The reviews should be as follows:

- **Third party audit by an accredited organization, expert, independent third party:** An audit of the documentation and calculations ensures that each number is traceable to its origin.
- **Expert (peer) review:** Although a detailed peer review would be appropriate when a procedure for determining CH_4 emissions is first adopted or revised; it would not be needed on an annual basis. Such a review is designed to ensure that the methodology is rigorous, accurate, and that the data and assumptions reflect the best available information.
- **Stakeholder review:** Review by industrial organizations and government can provide a forum for review of the methods used, such as a review of the emissions factors, and emissions avoided data, and
- **Public review:** Some countries make their entire inventory available for public review and comment. This process may result in a range of comments and issues broader than those from other review processes.

5 CONCLUSIONS

All estimates of total national emissions from coal mining, regardless of the selected methodology, should be calculated using the following general equation: Total Emissions = Emissions from Underground Mines + Emissions from Surface Mines + Emissions from Post-Mining Emissions - Emissions Avoided Due to Recovery. The *IPCC Guidelines* provide two general approaches to estimating CH_4 emissions from coal mining. The first (Tier 2 and Tier 1) uses coal production as the activity data and an emission factor based on methane emissions per unit of coal production. Tier 2 emissions factors require measurement data from underground mines within the country itself, whereas there are default Tier 1 emission factors for regions. The Tier 3 method uses mine-specific measurement data from ventilation and degasification systems to develop national estimates for underground mines. Given the large contribution to total emissions from underground mining, and the feasibility of collecting accurate measurement data from these mines, the best way to reduce uncertainty is to focus on the Tier 3 method. Wherever possible, the national emission estimates should be corrected for the amount of CH_4 that is used as fuel, by subtracting this amount from total estimated emissions

There are no methodologies for estimating emissions from abandoned mines or coal waste piles in the *IPCC Guidelines*, but if a country has data on which to base a measurement, it should do so in a transparent manner. For the purpose of transparency and comparability, it is important to disaggregate fugitive emissions from fossil fuels into coal mining, natural gas, and oil. The quality of all activity and emission factor data should be studied and reviewed in cooperation with the personnel responsible for collecting, compiling, and analyzing the data.

When the inventory agency applies emission factors from the literature, it should review the background data, measurements and assumptions used to come up with these emissions factors.

REFERENCES

Australian National Greenhouse Gas Inventory. (http://www.greenhouse.gov.au/inventory/natinv/95/95energy/n95_1b1.html)

International Panel on Climate Change (IPCC), 1996. *Greenhouse Gas Inventory Reference Manual (Revised)*. v.3.

International Energy Agency (IEA), „Energy Statistics and Balances of non-OECD Countries; Coal Information“, (http://www.iea.org/stats/files/keystats/p_0105.htm).

USEPA, 1993. *Anthropogenic Methane Emissions in the United States*, Global change Division, Office of Air and Radiation, Washington, DC.

USEPA, 1991. *Assessment of the Potential for Economic Development and Utilization of Coalbed Methane in Poland*, Office of Air and Radiation, Washington, DC.

USEPA, 1994. International Anthropogenic Methane Emissions: Estimates for 1990, Office of Policy, Planning and Evaluation, Washington, DC.

USEPA, 1993. Options for Reducing Methane Emission Internationally. Volume II: International Opportunities for Reducing Methane Emissions, Global change Division, Office of Air and Radiation, Washington, DC.

USEPA, 1996. Reducing Methane Emissions From Coal Mines in Russia, Office of Air and Radiation, Washington, DC.

USEPA, 1996. Reducing Methane Emissions From Coal Mines in China: The Potential for Coalbed Methane Development, Office of Air and Radiation, Washington, DC.

USEPA, (1998) Draft „Technical Assessment Report: Mitigation of Methane Emissions from Coal Mine Ventilation Air“

ANNEX 1 ESTIMATED UNDERGROUND EMISSIONS FACTORS FOR SELECTED COUNTRIES

Country	Emission Factors (m^3/tonne)	Source
Former Soviet Union	17.8 – 22.2	USEPA (1993c)
United States	11.0 – 15.3	USEPA (1993a)
Germany (East & West)	22.4	Zimmermeyer, 1989
United Kingdom	15.3	BCTSRE, 1992
Poland	6.8 – 12.0	Pilcher et al, 1991
Czechoslovakia	23.9	Bibler et al., 1991
Australia	15.6	Lama, 1992

ANNEX 2 SAMPLE EMISSIONS AVOIDED CALCULATION

Mine	Gas Sales in Each Year (m^3)							Years in advance of mining	Total Avoided (m^3)
	Y-6	Y-5	Y-4	Y-3	Y-2	Y-1	Y		
1	1050	1500	2000	2000	2200	1250	1250	4	2000
2	-	-	-	9000	9500	8000	8500	2	9500
3	5800	6000	6250	4000	3000	-	-	6	5800
4	1900	2200	2550	3000	3150	4000	4400	4	2550
5	-	-	-	9500	10000	10500	12000	6	0
Total									14630