VOLUME VIII: CHAPTER 4

METHODS FOR ESTIMATING METHANE EMISSIONS FROM COAL MINING

March 2005

Prepared by:
ICF Consulting

Prepared for:
State and Local Climate Change Program,
U.S. Environmental Protection Agency &
Emission Inventory Improvement Program

DISCLAIMER

ACKNOWLEDGMENTS

This chapter was originally written by staff of ICF Consulting in Washington, DC, drawing on a variety of sources. It has since been updated by Caren Mintz, Elizabeth Martin, Anne Choate, and other ICF staff under the direction of Andrea Denny of the U.S. Environmental Protection Agency's State and Local Climate Change Program. Elizabeth Scheehle of the U.S. EPA's Office of Air and Radiation also contributed to the preparation and review of this chapter.

CONTENTS

Figures and Tables

1

INTRODUCTION

The EIIP guidelines are designed to describe emission estimation techniques for greenhouse gas sources in a clear and unambiguous manner and to facilitate preparation of inventories at the state level. This chapter presents the methodology for estimating methane emissions from coal mining. The methodology presented in this chapter has been revised to reflect new activity data, emission factors, and methods pertaining to this source category. Where possible, the methodology has been updated to be consistent with the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002*.

Section 2 of this chapter contains a general description of this source category. Section 3 provides a listing of the steps involved in estimating methane emissions from coal mining. Section 4 presents the preferred estimation method. Section 5 is a placeholder for alternative estimation techniques that may be added in the future. A summary of uncertainty for this source category is provided in Section 6. References used in developing this chapter are identified in Section 7.

In addition to these guidelines, there are a series of user friendly spreadsheet tools available to assist in the development of emission inventories at the state level. Please consult the Coal Mining Module of the State Inventory Tool[1] to calculate emissions from this source category using the preferred emission estimation method.

[1] Note: The spreadsheet tool may have a different order of calculations, and may not show all calculations to the user.

2

SOURCE CATEGORY DESCRIPTION

2.1 EMISSION SOURCES

There are three sources of methane (CH_4) emissions from coal mining: underground mining, surface mining, and post-mining activities.[2] Emissions from post-mining activities may be further subdivided into emissions from underground-mined coal and emissions from surface-mined coal. Each of these emission sources is described in more detail below.

Because CH_4 is a safety hazard in underground mines, substantial research has been undertaken to determine how to predict and control CH_4 emissions in mine working areas. Similar research has not yet been undertaken for surface mines, which emit smaller quantities of CH_4 and usually do not have similar safety issues associated with them.

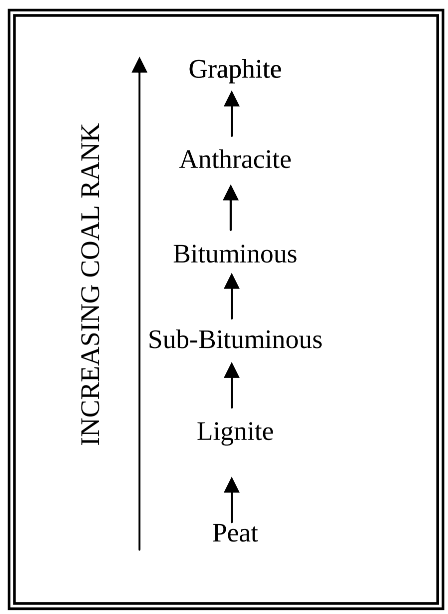
2.1.1 Overview of Coalbed Methane Production[3]

Coalbed Methane Production

Coal is formed over millions of years as organic matter is transformed by complex processes known as "coalification." Coalification is controlled by chemical and physical processes, temperature, pressure, and geologic history. Differing levels of coalification produce different "ranks" of coal, as shown in Figure 4.2-1.[4] Coalification results in both physical and chemical changes, including CH_4 generation. Other byproducts of the coalification process are water and carbon dioxide.

The amount of CH_4 produced increases throughout the coalification process. Thus, higher ranked coals tend to contain more CH_4 than lower ranked coals.

Figure 4.2-1: Stages in Coalification



[2] Future editions of the guidance for this source may also include a methodology for estimating emissions from abandoned mines. These methods have not yet been developed due to limited data.

[3] This overview section is adapted from the coal mining chapter of the U.S. EPA Report to Congress entitled *Anthropogenic Methane Emissions in the United States: Estimates for 1990*.

[4] Higher rank coals contain more fixed carbon, less volatile matter, and less moisture.

Methane Storage in Coal

CH_4 is stored in the coal itself and can also be contained in the surrounding strata. Large amounts of CH_4 can be stored within the microstructure of coal. CH_4 storage in coalbeds, mainly through adsorption onto internal coal surfaces, is a function of rank and pressure.[5] In general, coals of increasing rank have higher CH_4 storage capacities. In addition, storage capacity increases almost linearly with increasing pressure, which in turn is a function of depth of the coal seam. Therefore, among coal seams of the same rank, deeper seams store more CH_4.

CH_4 is released when pressure within a coalbed is reduced, either through mining or through natural erosion or faulting. CH_4 will migrate through coal from zones of higher concentration to zones of lower concentration until it intersects a pathway, such as a joint system or fracture. The size, spacing, and continuity of such pathways determine the permeability of the coal and control the flow of CH_4 through the coal to the surface or the mine workings.

As pressure is reduced during mining, CH_4 is liberated from the seam being mined and from surrounding strata. In addition to the rank and depth of the coal, the amount of disturbance to the surrounding strata as a result of mining activities will also determine the quantity of CH_4 released. The amount of CH_4 liberated by mining activities can exceed the amount of gas contained in the mined coal by as much as 3 to 9 times (Kissell et al. 1973).

U.S. Mining Techniques

In the United States, coal is produced in underground and surface mines. Coalbeds shallower than about 250 feet are generally mined from the surface, while deeper coalbeds are usually mined by underground methods. As mentioned earlier, underground mines contain more CH_4 than surface mines; thus, underground mines liberate more CH_4 than surface mines.

2.1.2 Underground Mining

Coal mined at underground mines accounted for about 40 percent of total U.S. coal production in 1990, and the proportion of underground to surface production has declined from 1990 through 2000. Most underground mining occurs in the Eastern United States, primarily in the Northern and Central Appalachian Basins (which are located in Pennsylvania, Virginia, West Virginia, Ohio, and Kentucky), and in the Black Warrior Basin of Alabama.

U.S. underground mines range from less than 1,000 to over 2,000 feet deep. Although CH_4 may be emitted during construction of underground mines, the bulk of the CH_4 is emitted during coal extraction, when controlled blasts create pathways for the CH_4 to move into the mine workings from unmined areas of the target coal seam and other strata.

Two underground mining methods are commonly used in the United States: room-and-pillar mining and longwall mining. The choice between these methods depends on geologic factors

[5] Adsorption is the adhesion of an extremely thin layer of molecules to the surfaces of solid bodies with which they are in contact.

(such as depth, terrain, and width of coalbed) and economic factors, such as equipment cost. Room-and-pillar mining is the more common underground mining technique in the United States, although longwall mines produce a majority of the underground coal. Mechanized longwall mining was introduced in the United States during the 1960s, and today there are around 60 longwall mines in operation (Reid 1997, Fiscor 2002). Longwall mines are typically bigger and deeper than room-and-pillar mines. They are also more expensive to equip and operate, but generally have higher coal production rates. The higher production, coupled with the more extensive caving typically associated with longwall mines, tends to result in higher methane emissions.

Methane Management Systems for Underground Mining

CH_4 is a serious safety threat in underground coal mines because it is highly explosive in atmospheric concentrations of 5 to 15 percent. The U.S. Mine Safety and Health Administration (MSHA), an agency of the U.S. Department of Labor, requires close monitoring of CH_4 levels to ensure that CH_4 concentrations in underground mines are kept below explosive levels. In mine entries used by personnel, CH_4 levels cannot exceed one percent, and in certain designated areas of the mine not frequented by mine personnel, CH_4 levels cannot exceed two percent. If these concentrations are exceeded, MSHA requires that coal production cease until CH_4 concentrations are reduced to acceptable levels.

There are two methods for controlling CH_4 in underground mines: use of ventilation systems and use of degasification systems. Ventilation systems are employed at all underground mines surveyed by MSHA.[6] The decision to use a degasification system is based primarily on safety factors, but may also be greatly influenced by the opportunity to sell or use the recovered gas. In especially gassy mines, the use of a ventilation system alone may be inadequate to degasify a mine so that it meets federal regulations with regard to maximum CH_4 concentrations. In such cases, a degasification system may be installed to help degasify the mine prior to, during, or after mining. The CH_4 recovered from these systems is usually of sufficient quality that the CH_4 can be sold to a pipeline or used for any number of applications, including electricity generation. In 2000, 21 of the more than 700 underground mines in the United States had degasification systems. In addition to the potential economic benefits associated with the sale of this gas, such projects have the added advantage of reducing CH_4 emissions.

The various methods of controlling CH_4 in underground mines are summarized in Table 4.2-1.

[6] Only those underground mines with detectable CH_4 emissions are surveyed by the MSHA. Detectable emissions are defined by MSHA as CH_4 concentrations at the mine entrance greater than 50 parts per million CH_4. Readings below this threshold are considered non-detectable.

Table 4.2-1: Approaches for Methane Control at Underground Mines

Method	Description
Ventilation	• Universal method to dilute and exhaust CH_4 to the atmosphere. • Sufficient, in most mines, to maintain safe mining conditions. • In the gassiest mines, supplemental degasification systems are required.
Degasification Techniques:	
Surface Wells in Advance of Mining	• Remove CH_4 before mining operations begin. • Can recover large amounts of pipeline quality CH_4. • Can produce CH_4 from multiple coal seams.
Gob Wells	• Surface wells used in longwall mining to remove CH_4 from portions of overlying strata ("gob areas") allowed to collapse after mining. • Can recover large amounts of CH_4 (quality of recovered CH_4 varies).
Horizontal Boreholes	• Drilled from inside the mine to degasify the coal seam being mined, either years in advance of mining or shortly before mining. • CH_4 is removed through an in-mine piping system. • Can recover pipeline quality gas.
Cross-Measure Boreholes	• Drilled from inside the mine to degasify the overlying or underlying coal and rock strata. • CH_4 is removed through an in-mine piping system. • Gas can become contaminated with mine air during production. • Used infrequently in the United States.

Source: U.S. EPA 1997.

2.1.3 Surface Mining

Surface mining is used to mine coal at shallow depths. In essence, it involves large-scale earth-moving; the overburden on top of the coal is excavated followed by removal of the coal.

In 2000, almost 700 million tons of coal was produced at surface mines, mostly in sub-bituminous and lignite mines in the Western United States. This represented about 65 percent of total U.S. coal production. The largest and fastest growing surface mining region is the Powder River Basin of Wyoming and Montana. Surface mines are also located in the lignite fields of North Dakota, South Dakota, and Montana, and in the Eastern bituminous coal basin in Illinois, Indiana, and western Kentucky.

2.1.4 Post-Mining

Not all of the CH_4 contained in coal is released during mining. Some CH_4 remains in the coal after it is removed from the mine and can be emitted as the coal is transported, processed, and stored. Depending on the characteristics of the coal and the way it is handled after leaving the mine, the amount of CH_4 released during post-mining activities can be significant and can continue for weeks or months. The greatest releases occur when coal is crushed, sized, and dried in preparation for industrial or utility uses (U.S. EPA 1990).

2.2 FACTORS INFLUENCING EMISSIONS

Of the emission sources described above, emissions from underground mining contribute by far the largest proportion of national CH_4 emissions from coal mining, accounting for about 65-70 percent of the total emissions from this sector. Emissions from surface mines and post-mining activities account for the remainder. Thus, the factors that have the greatest impact on emissions are those related to underground mining.

As discussed earlier, the amount of CH_4 generated during coal mining depends on the type of mine, gas content of the coal seam, mining methods, and other factors such as moisture. Emissions are also affected by the amount of coal mined: the greater the quantity of coal mined the greater the amount of CH_4 released. High ranks of coal generally contain more CH_4 than low ranks. Between two coal seams with the same rank, the deeper seam will contain more CH_4, because it is under more pressure. The amount of CH_4 emitted depends not only on the amount generated, but also on whether a degasification system with CH_4 recovery is used. Surface seams have the lowest CH_4 content and generally do not support the use of degasification systems.

3

OVERVIEW OF AVAILABLE METHODS

A three-part approach is used to estimate methane (CH_4) emissions from coal mining. Emissions from underground mining are estimated on a mine-specific basis; emissions from surface mining and post-mining activities are estimated using a basin-specific approach.

There are two sources of emissions from underground mining: (1) CH_4 emitted from underground ventilation systems and (2) CH_4 emitted from degasification systems. Emissions from underground ventilation systems are calculated by summing the CH_4 emissions from ventilation systems at each underground mine in the state. Emissions from CH_4 degasification systems are calculated by summing reported or estimated emissions of CH_4 from all mines with degasification systems in the state, and then subtracting the CH_4 that is recovered and used for energy purposes. The total CH_4 emitted from underground mines is the sum of CH_4 emissions from ventilation and degasification systems.

Estimating CH_4 emitted from surface mining involves multiplying (1) the quantity of surface-mined coal from each coal basin in a state by (2) the appropriate emission factor for that basin. A basin-specific approach is also used to determine post-mining emissions.

The total CH_4 emitted from coal mines is the sum of (1) CH_4 emitted from underground mines plus (2) CH_4 emitted from surface mines plus (3) CH_4 emitted from post-mining activities. This approach is described in detail in the next section.

CH_4 Emissions from Coal Mining = Underground Mine Emissions (Underground CH_4 Liberated[7] – CH_4 Used) + Surface Mine Emissions + Post-Mining Emissions (from Underground- and Surface-Mined Coal)

The methods described here are the Intergovernmental Panel on Climate Change (IPCC) "Tier 2" (and "Tier 3" for Underground Mine Emissions) methods presented in *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC/UNEP/OECD/IEA 1997). These methods are consistent with those used to estimate coal mining emissions in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002* (U.S. EPA 2004a).

[7] Underground CH_4 liberated is the sum of CH_4 collected by ventilation and degasification systems

4

PREFERRED METHOD FOR ESTIMATING EMISSIONS

Methane (CH_4) liberated during coal mining may originate from underground mine ventilation/ degasification systems, from surface mines, or from post-mining activities (from underground- and surface-mined coal). In states where underground mines have degasification systems, emissions from underground mines will need to be adjusted to reflect CH_4 recovered by a degasification system.

The following seven steps are required to estimate CH_4 emissions from this source:

(1) obtain required data;

(2) estimate CH_4 liberated through ventilation systems;

(3) calculate CH_4 emissions from degasification systems;

(4) estimate CH_4 emitted from surface mines;

(5) estimate CH_4 emitted from post-mining activities;

(6) calculate total CH_4 emissions from coal mining; and

(7) convert units to metric tons of carbon equivalent (MTCE).

Step (1): Obtain Required Data

- *Required Data*. To estimate underground mining emissions, states will need to know the quantity of CH_4 emitted from ventilation systems at all mines in the state in ft^3. In addition, states that have mines with degasification systems will need to ascertain the quantity of CH_4 emitted and recovered from degasification systems in ft^3. Surface mining emissions and post-mining emissions (from both underground- and surface-mined coal) can be estimated using data on the state's annual coal production (tons), grouped by underground and surface production.

- *Data Sources*. The Non-CO_2 Gases and Sequestration Branch (NGSB) in the U.S. EPA's Office of Air and Radiation develops estimates of CH_4 emissions from coal mining for the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA 2004a). For underground mines, NGSB has compiled a database with mine-specific information on ventilation emissions and recovery from degasification systems. These data are aggregated by state and provided in the Coal Mining Module of the State Inventory Tool (hereafter referred to as the

State Inventory Tool) as default activity data. These data can also be obtained from the U.S. EPA's Coalbed Methane Outreach Program (CMOP). CMOP information can be found online at http://www.epa.gov/coalbed/index.htm. Ventilation emissions data and a list of mines with active degasification systems may also be obtained from Mine Safety and Health Administration (MSHA) district offices. A complete listing of MSHA district offices can be found at http://www.msha.gov. Note that if data is obtained directly from MSHA, states must account for periods when the mine is active but not venting.

Coal production data, for calculation of emissions from surface mines and post-mining activities, may be available from a state coal agency; alternatively, state data are provided in the State Inventory Tool. The data in the tool are taken from the Energy Information Administration publications *Coal Industry Annual* and *Annual Coal Report 2002* (EIA 2001, 2003), which can be accessed at http://www.eia.doe.gov/cneaf/coal/page/pubs.html.

Step (2): Estimate Methane Liberated from Ventilation Systems in Underground Mines

CH_4 liberated from underground mining consists of CH_4 emitted by ventilation systems and degasification systems. This step details procedures for estimating emissions from ventilation systems; Step 3 describes methods for estimating emissions from degasification systems.

- *Measured Ventilation Emissions from Underground Mines*. Sum the quantity of CH_4 emissions from ventilation systems for all underground mines in the state. Default ventilation emissions data (in ft^3) are provided in the State Inventory Tool. If none of the mines in the state have degasification systems, CH_4 liberated from ventilation systems comprises the total emissions from underground mines. For all other coal producing states, emissions from ventilation systems will need to be added to emissions from degasification systems, as described in Step 3.

Step (3): Calculate Methane Emissions from Degasification Systems

The amount of CH_4 vented from degasification systems in underground mines equals the amount of CH_4 recovered minus the amount used for energy purposes. States without mines with degasification systems may skip this step.

- *Methane Recovery from Degasification Systems.* There are three ways to determine recovery from degasification systems:

  (1) States can access estimates of degasification system emissions using the State Inventory Tool. The tool provides the sum of emissions (in ft^3) across all mines in each state. The default activity data provided in the tool were calculated using a combination of the two methods described below.

  (2) States may obtain information on degasification system CH_4 recovery from individual mine operators.

  (3) Alternatively, an estimate of recovery system efficiency can be used to estimate degasification system recovery. The recovery efficiency is a measure of the amount of CH_4 that is removed relative to the amount of CH_4 that would have been vented if there

were no degasification system in place. If mine-specific estimates of efficiency are not available, a default value of 40 percent may be used (U.S. EPA 1997).

- *Recovered CH_4 Use*. As noted under Step 1, NGSB collects information to generate estimates of CH_4 emissions from coal mining for the national inventory. This information includes the quantity of CH_4 recovered by degasification systems and used for energy recovery in each state. The sum of CH_4 recovered and used from degasification systems (in ft^3) in each state is provided in the State Inventory Tool. However, not all mines have degasification systems; default values should only be applied for mines with these systems.

- *Vented Emissions from Degasification Systems*. If none of the recovered CH_4 is used as an energy source, then degasification system emissions equal the amount of CH_4 recovered from the mine. If some or all of the recovered CH_4 is used for energy, this portion is deducted from the amount recovered to determine the amount emitted.

Example:	In 2000, CH_4 emissions from underground mine ventilation systems in West Virginia measured 18,377 million ft^3, CH_4 recovery from degasification systems totaled 6,230 million ft^3, and 1,680 million ft^3 of recovered CH_4 were used for energy.
	Ventilation emissions + (CH_4 recovered – CH_4 used) = Total CH_4 liberated from underground mines in West Virginia
	= 18,377 million ft^3 + (6,230 million ft^3 – 1,680 million ft^3)
	= **22,927 million ft^3 CH_4**

Step (4): Estimate Methane Emitted from Surface Mines

CH_4 emissions from surface mines are estimated by multiplying the state's surface coal production in each coal basin by an emission factor based on the in-situ CH_4 content for the surface coal found in each coal basin. A state's annual surface coal production can be found in *Coal Industry Annual* and *Annual Coal Report* (EIA 2001, 2003). The emission factor, which is given on a basin-specific basis and can be found in Table 4.4-1, accounts for CH_4 liberated from the coal itself and from surrounding strata. Two states—Kentucky and West Virginia—span more than one coal basin. For these two states, emissions are determined by county-level surface coal production. The counties and their associated basins are listed below.

Kentucky

- **Western Kentucky Counties (in the Illinois Basin)**: Butler, Caldwell, Crittendon, Christian, Daviess, Edmonston, Grayson, Hancock, Henderson, Hopkins, Logan, McLean, Muhlenberg, Ohio, Todd, Union, Webster.

- **Eastern Kentucky Counties (in the Central Appalachian Basin)** All other coal-producing counties in Kentucky.

West Virginia[8]

- **Northern Counties (in the Northern Appalachian Basin)**: Barbour, Braxton, Brooke, Gilmer, Grant, Harrison, Lewis, Marion, Marshall, Mineral, Monongalia, Ohio, Pendelton, Preston, Randolph, Taylor, Tucker, Upshur, Webster.

- **Southern Counties (in the Central Appalachian Basin)**: All other coal-producing counties in West Virginia

Total CH_4 Emissions from Surface Mines = Total Surface Coal Production in State x Basin-Specific CH_4 Emission Factor for Coal Produced from Surface Mines

***Example*:** According to U.S. DOE's *Coal Industry Annual 2000* (EIA 2001), in 2000 West Virginia's northern counties produced 5,919,000 tons of coal from surface mines, and its southern counties produced 54,498,000 tons of coal from surface mines.

West Virginia's northern counties (Northern Appalachian Basin):
5,919,000 tons x 119.0 ft^3/ton = 704,361,000 ft^3 CH_4 emitted

West Virginia's southern counties (Central Appalachian Basin):
54,498,000 tons x 49.8 ft^3/ton = 2,714,000,400 ft^3 CH_4 emitted

Total CH_4 emissions from surface mines in West Virginia:
(704,361,000 + 2,714,000,400) ft^3= **3,418,361,400 ft^3 CH_4 emitted**

Table 4.4-1: Methane Emission Factors for Coal Produced from Surface Mines

Basin	Emission Factor (ft^3 CH_4/ton of coal mined)
Central Appalachian Basin: *Eastern Kentucky, Tennessee, Virginia, Southern West Virginia*	49.8
Northern Appalachian Basin: *Maryland, Ohio, Pennsylvania, Northern West Virginia*	119.0
Black Warrior Basin: *Alabama*	61.4
Southwest and Rockies Basins: *New Mexico, Arizona, California*	14.6
Southwest and Rockies Basins: *Colorado*	66.2
Southwest and Rockies Basins: *Utah*	32.0
Illinois Basin: *Illinois, Indiana, Western Kentucky*	68.6
North Great Plains Basin: *Montana, North Dakota, Wyoming*	11.2
Northwest Basin: *Alaska, Washington*	11.2
West Interior Basin: *Iowa, Kansas, Missouri*	68.6
West Interior Basin: *Arkansas, Oklahoma*	149.0
West Interior Basin: *Louisiana, Texas*	66.2

Source: U.S. EPA 1996 2004b.

[8] Note that the emission factors currently listed in Table 4.4-1 for the Northern and Southern Counties of West Virginia are identical. Although this makes the distinctions in coal production between the two Appalachian Basins moot for this step of the analysis, there are meaningful distinctions by county in the next step.

Step (5): Estimate Methane Emitted from Post-Mining Activities

The U.S. EPA estimates that CH_4 emitted during post-mining activities, such as transportation and handling of coal, equals 33 percent of the in-situ CH_4 content for the coal (U.S. EPA 1993). U.S. EPA has used this formula to develop post-mining emission factors, as shown in Table 4.4-2. Post-mining emissions must be calculated separately for underground- and surface-mined coal.

Total Post-Mining CH_4 Emissions = (Total Coal Production from Underground Mines in State x Basin-Specific Post-Mining CH_4 Emission Factor for Underground-Mined Coal) + (Total Coal Production from Surface Mines in State x Basin-Specific Post-Mining CH_4 Emission Factor for Surface-Mined Coal)

Example

According to EIA's *Coal Industry Annual 2000* (EIA 2001), in 2000 West Virginia's northern and southern counties produced 32,281,000 tons and 66,158,000 tons, respectively, from underground mines. The state's surface mines produced 5,919,000 tons and 54,498,000 tons from the northern and southern counties, respectively.

Post-Mining CH_4 Emissions from Underground-Mined Coal:

Northern Counties = 32,281,000 tons x 45.0 ft^3/ton = 1,452,645,000 ft^3
Southern Counties = 66,158,000 tons x 44.5 ft^3/ton = 2,944,031,000 ft^3
Total = 4,396,676,000 ft^3

Post-Mining CH_4 Emissions from Surface-Mined Coal:

Northern Counties = 5,919,000 tons x 8.1 ft^3/ton = 47,943,900 ft^3
Southern Counties = 54,498,000 tons x 19.3 ft^3/ton = 1,051,811,400 ft^3
Total = 1,099,755,300 ft^3

Total Post-Mining CH_4 Emissions in West Virginia:

= 4,396,676,000 ft^3 + 1,099,755,300 ft^3
= **5,496,431,300 ft^3 CH_4**

Table 4.4-2: Post-Mining Methane Emission Factors for Underground- and Surface-Mined Coal

Basin	Underground Mines (ft^3 CH4/ ton coal mined)	Surface Mines (ft^3 CH4/ ton coal mined)
Central Appalachian Basin: *Southern West Virginia*	44.5	19.3
Central Appalachian Basin: *Virginia*	129.7	19.3
Central Appalachian Basin: *Eastern Kentucky, Tennessee*	20.0	19.3
Northern Appalachian Basin: *Maryland, Ohio, Pennsylvania, Northern West Virginia*	45.0	8.1
Black Warrior Basin: *Alabama*	86.7	10.0
Southwest and Rockies Basins: *New Mexico, Arizona, California*	34.1	2.4
Southwest and Rockies Basins: *Colorado*	63.8	10.8
Southwest and Rockies Basins: *Utah*	32.3	5.2
Illinois Basin: *Illinois, Indiana, Western Kentucky*	20.9	11.1
North Great Plains Basin: *Montana, North Dakota, Wyoming*	5.1	1.8
Northwest Basin: *Alaska*	52.0	1.8
Northwest Basin: *Washington*	15.4	1.8
West Interior Basin: *Iowa, Kansas, Missouri*	20.9	11.1
West Interior Basin: *Arkansas, Oklahoma*	107.6	24.2
West Interior Basin: *Louisiana, Texas*	41.6	10.8

Source: U.S. EPA 1996, 2004b.

Step (6): Calculate Total Methane Emissions from Coal Mining

Total CH_4 emissions from coal mining are calculated by summing the results from Steps 2-5.

Total CH_4 Emissions from Coal Mining = (Total CH_4 Liberated from Underground Mines - CH_4 Recovered by Degasification Systems and Used for Energy) + Total CH_4 Emissions from Surface Mines + Total CH_4 Emissions from Post-Mining Activities

> Example: For the state of West Virginia, total CH_4 emissions from coal mining in 2000 are calculated as follows:
>
> Total CH_4 Emissions from Coal Mining = (18,377 million ft^3 CH_4 ventilated from underground mines + 6,230 mcf recovered CH_4 – 1,680 million ft^3 CH_4 from systems used for energy) + 3,418 million ft^3 CH_4 emissions from surface mines + 5,496 million ft^3 CH_4 emissions during post-mining activities
>
> = **31,841 million ft^3 of CH_4**

Step (7): Convert Units to Metric Tons of Carbon Equivalent

The resulting value is then converted to MTCE by first converting ft^3 to grams by multiplying by 19.2 grams/ft^3 CH_4. Next, convert from grams to metric tons by multiplying by 1 metric ton/1,000,000 grams, by 21 (the Global Warming Potential of CH_4), and by12/44 (the ratio of the atomic weight of carbon to the molecular weight of CO_2), to obtain results in MTCE.

MTCE = ft^3 CH_4 x 19.2 g/ft^3 CH_4 x 1 metric ton/1,000 g x 21 x 12/44

Example:	Convert to MTCE:
	31,841,000,000 ft^3 CH_4 x 19.2 g/ft^3 CH_4 x 1 metric ton/1,000,000 g x 21 x 12/44 = **3,501,352 MTCE**

5

ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

There are no alternative methods for estimating state-level emissions from coal mining at this time.

6

UNCERTAINTY SUMMARY

The total quantity of methane (CH_4) emissions from coal mining depends on the amount of CH_4 liberated from underground mining, surface mining, and post-mining activities. The calculation approach recommended in this chapter follows the IPCC Guidelines (IPCC/UNEP/OECD/IEA 1997) and the methodology used in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (U.S. EPA 2004). Uncertainty exists in each sub-category, primarily in the emission measurements and factors used.

The uncertainty surrounding CH_4 emissions from underground mines is relatively low. Estimates of emissions from ventilation systems are based on actual measurement data, and thus are considered rather certain. The frequency of measurements (quarterly, rather than continuous) and the functionality of the measurement equipment introduce a low level of uncertainty into these estimates. Similarly, emissions from degasification systems have low level uncertainty, due to potential errors in determining the size of each well's drainage area.

Surface mining and post-mining emissions are greater sources of uncertainty because of the inherent inaccuracies associated with developing emission factors from field measurements. However, these subcategories represent a much smaller portion of total emissions from coal mining than underground mines. Therefore overall uncertainty for this source category remains low.

7

REFERENCES

EIA. 2003. *Annual Coal Report 2002*. Energy Information Administration, U.S. Department of Energy. Internet address: http://www.eia.doe.gov/cneaf/coal/page/pubs.html.

EIA. 2001. *Coal Industry Annual, 2000*. Energy Information Administration, U.S. Department of Energy. Internet address: http://www.eia.doe.gov/cneaf/coal/page/pubs.html.

Fiscor, S. 2002. "U.S. Longwall Census 2002: Coal Operators Invest in Longwall Technology," *Coal Age,* February.

IPCC/UNEP/OECD/IEA. 1997. *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change, United Nations Environment Programme, Organization for Economic Co-Operation and Development, International Energy Agency. Paris, France.

Kissell, F.N., C.M. McCulloch, and C.H. Elder. 1973. *The Direct Method for Determining Methane Content of Coalbeds for Ventilation Design*. U.S. Bureau of Mines Information Circular 7767, U.S. Department of the Interior. Washington, D.C.

Masemore, S., S. Piccot, E. Ringler, and W. P. Diamond, 1996, Evaluation and Analysis of Gas Content and Coal Properties of Major Coal Bearing Regions of the United States, EPA-600/R-96-065, Washington, D.C.

Reid, B. 1997. "International Longwall Census, Part 1," *Coal Age*, September.

U.S. EPA. 2004a. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2002*. U.S. Environmental Protection Agency. EPA 430-R-04-003. Internet address: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2004.html.

U.S. EPA. 2004b. *Coalbed Methane Emissions Estimates Database, 2004.* U.S. Environmental Protection Agency, Office of Air and Radiation. Washington, DC.

U.S. EPA. 1997. *Identifying Opportunities for Methane Recovery at U.S. Coal Mines: Draft Profiles of Selected Gassy Underground Coal Mines*. U.S. Environmental Protection Agency, Office of Air and Radiation. Washington, DC.

U.S. EPA 1996. Masemore, S., S. Piccot, E. Ringler, and W. P. Diamond, 1996, *Evaluation and Analysis of Gas Content and Coal Properties of Major Coal Bearing Regions of the United States*, EPA-600/R-96-065, Washington, D.C.

U.S. EPA. 1993. *Anthropogenic Methane Emissions in the United States: Estimates for 1990*. Report to Congress. U.S. Environmental Protection Agency, Office of Air and Radiation. EPA 430-R-93-003. April. Washington, DC.

U.S. EPA. 1990. *Methane Emissions from Coal Mining: Issues and Opportunities for Reduction*. U.S. Environmental Protection Agency, Office of Air and Radiation. Washington, DC.