TECHNICAL SUPPORT DOCUMENT FOR UNDERGROUND COAL MINING: RULE FOR MANDATORY REPORTING OF GREENHOUSE GASES

Office of Air and Radiation
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CONTENTS

1. Source Description

Coal production in the United States reached a record level in 2006, with production of 1,163 million short tons, according to the Energy Information Administration (EIA 2007). This was produced from 1,424 mines, of which, 612 were underground mines and 812 were surface mines.[1]

Two greenhouse gas (GHG) emissions are of concern in the coal mining sector. The first and largest source of emissions is fugitive emissions of methane (CH_4) released from the coal and surrounding rock strata due to mining activities. There are five primary sources of fugitive CH_4 emissions from coal mining operations:

- Ventilation air from underground mines, which contains dilute concentrations of CH_4
- Degasification systems at underground coal mines (also commonly referred to as drainage systems). These systems may employ vertical and/or horizontal wells to recover CH_4 in advance of mining (known as "pre-mine drainage") or after mining (called "gob" or "goaf" wells)
- Fugitive emissions from post-mining operations, during which coal continues to emit CH_4 as it is stored in piles, processed, and transported
- Surface mines, from which CH_4 in the coal seams is directly exposed to the atmosphere
- Abandoned or closed mines, from which CH_4 may seep out through vent holes or through fissures or cracks in the ground.

The second source of GHG emissions -- combustion-related CO_2 emissions -- are associated with the use of energy in mining operations, both from stationary and mobile sources, for both surface and underground mines. In some cases, CH_4 produced from the coal mine itself is combusted as a source of energy.

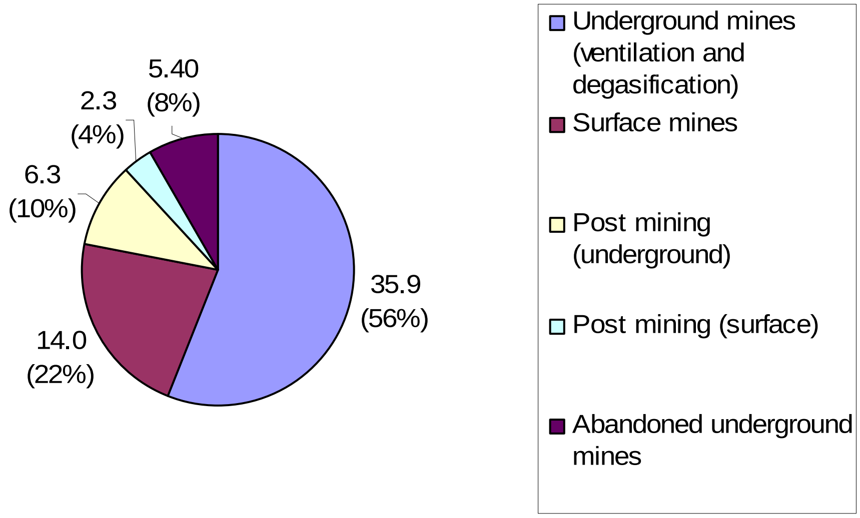
Total Emissions (based on Inventory)

The annual *Inventory of U.S. GHG Emissions and Sinks* considers active coal mining-related fugitive CH_4 emissions to the atmosphere from three sources: underground mining, surface mining, and post-mining (i.e., coal-handling) activities (EPA 2008). Total CH_4 emissions from active mining operations in 2006 were estimated to be 58.5 million metric tons of CO_2 equivalent (CO_2e) from these sources, a decline of 30% since 1990. Of this, underground mines accounted for 35.9 million metric tons of CO_2e, surface mines accounted for 14.0 million metric tons of CO_2e, and post-mining emissions accounted for 8.6 million metric tons of CO_2e. Fugitive CH_4 emissions from inactive, closed (or abandoned) coal mines were estimated to contribute another 5.4 million metric tons of CO_2e.

The relative contribution of the various sources of coal mine emissions is illustrated in Figure 1.

[1] An underground mine is where coal is produced by tunneling into the earth to the coalbed, which is then mined with equipment such as cutting machines and continuous, long wall, and shortfall mining machines. Underground mines are classified according to the type of opening used to reach the coal, i.e., drift (level tunnel), slope (inclined tunnel), or shaft (vertical tunnel). In contrast, surface mines are mines that are usually within a few hundred feet of the surface. Earth and rock above or around the coal (overburden) is removed to expose the coalbed, which is then mined with surface excavation equipment such as draglines, power shovels, bulldozers, loaders, and augers. Surface mines include: area, contour, open-pit, strip, and auger mines.

Figure 1
Estimated Fugitive CH_4 Emissions from U.S. Coal Mines (2006)



Source: Environmental Protection Agency, *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006,* USEPA #430-R-08-005, April 2008

Coal mining operations require a wide variety of equipment that uses coal, distillate, residual fuel oil, natural gas, gasoline, and purchased electricity, and hence, results in emissions from combustion. An estimated 9 million metric tons of CO_2 equivalent emissions were associated with energy use in coal mining operations in the United States in 2006 (see discussion below).

<u>Types of Emissions to be Reported</u>

i) Process Emissions

Five categories of CH_4 emissions from the coal mining sector are addressed in the U.S. national inventory:

- Ventilation air from underground mines
- Degasification systems at underground coal mines
- Fugitive emissions from post-mining operations
- Surface mines
- Abandoned and/or closed mines.

The nature of each of these sources of emissions, and considerations associated with various options for inclusion in the proposed rulemaking, are discussed in more detail below.

<u>Underground mines – mine ventilation emissions</u>

Mine ventilation emissions from underground coal mines account for the largest share of fugitive CH_4 emissions -- 32.8 million metric tons of CO_2e, or 56% of all U.S. coal mining fugitive emissions. In underground mines, CH_4 can create an explosive hazard to coal miners. To ensure mine safety, fresh air is circulated through underground coal mines using ventilation systems to dilute in-mine concentrations of CH_4 to well below explosive levels. In the U.S., mine safety authorities at the Mine Safety and Health Administration (MSHA) regulate these concentrations. Typically, CH_4 concentrations in ventilation air range from 0.1% to 1.0%. These ventilation systems can exhaust significant amounts of CH_4 to the atmosphere in relatively low concentrations.

MSHA field inspectors, as part of periodic mine safety inspections, conduct air sampling according to well-defined procedures for mines with CH_4 emissions exceeding defined thresholds (see discussion below). The results of this sampling currently provide the basis for estimating CH_4 emission rates from ventilation systems at underground coal mines for the EPA *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (EPA, 2008).

Underground mines – Degasification

In many cases, it is necessary to supplement the mine ventilation with a CH_4 degasification system. Methane drainage must be performed when the ventilation system cannot dilute CH_4 emissions from the mine to below statutory levels. Mines that employ degasification systems also liberate large quantities of CH_4 in relatively high concentrations. Degasification systems use wells drilled from the surface or boreholes drilled inside the mine to remove CH_4 before, during, or after mining operations. These degasification systems usually consist of a network of boreholes, pumping systems, and gas gathering pipelines. The majority of the CH_4 liberated from degasification systems is input into natural gas pipelines, is used for energy on site, or is combusted by flaring. Of the 21.8 million metric tons CO_2e of CH_4 liberated by degasification systems in 2006, 18.7 million metric tons CO_2e of CH_4 was combusted, and 3.1 million metric tons were emitted to the atmosphere.

In 2006, twenty U.S. coal mines supplemented their ventilation systems with active degasification systems. Thirteen coal mines collected CH_4 from degasification systems and sold this gas to a pipeline. One coal mine used CH_4 from its degasification system onsite to heat mine ventilation air. Two of the coal mines that sold gas to pipelines also used CH_4 to generate electricity or fuel a thermal coal dryer on site (EPA 2008).

Before mining, drainage wells are drilled through a coal seam or seams to pre-drain the CH_4. The wells are normally placed in operation 2 to 7 years ahead of mining and the coal seam is often hydraulically fractured to remove much of the CH_4 and water from the seam. These pre-mine drainage wells can recover relatively high-quality gas from the coal seam and the surrounding strata in most cases because the CH_4 is not diluted by ventilation from the mine. The total amount of CH_4 recovered depends on site-specific conditions such as the gas content of the coal seams and surrounding strata, permeability of the geologic materials, the drainage time, the amount of pressure differential applied, and other characteristics of the geologic and extractive systems. Such pre-mine drainage wells can recover 50% to 90% of the gas content of the coal.

Horizontal holes can also be drilled into the coal seam from development entries in the mine to drain CH_4 from the unmined areas shortly before mining, reducing the flow of CH_4 into the mining section. In this case, because CH_4 drainage occurs only from the mined coal seam, and the period of drainage is relatively short, and the recovery efficiency of this technique is relatively low -- normally, about 10% to 20% of the CH_4 is recovered from the drilled area. Higher recoveries can generally be achieved in room-and-pillar sections by drilling longer holes farther in advance of mining.

Gob wells and cross-measure bore holes recover CH_4 from the overburden (i.e., gob area) after mining of the seam, primarily in longwall mines. The gob area is a fractured zone in a mine seam that is the result of the relaxation and collapse of strata surrounding the mined coal seam. Such "gobs" can be significant sources of CH_4 emissions. Gob gas vent holes drilled into mine gobs after mining generally vent the degasified CH_4 directly to the atmosphere. These are typically equipped with exhausters on the surface to draw the gas from the gob. Monitoring equipment may or may not be equipped as part of the surface infrastructure for these gob gas vent wells, but would generally be in place where the collected gas is sold or used onsite.

In many cases, the CH_4 recovered from degasification systems can be productively utilized. Methane emitted from coal mine ventilation systems constitutes an unused potential source of energy. Utilization technologies for recovered coal mine CH_4 fall into three broad categories: 1) natural gas substitution, 2) direct use at or near the mine site, and 3) electricity generation and/or cogeneration. High quality coal mine gas may require only modest processing before compression and pipeline injection, while medium-quality coal mine gas may require some processing or upgrading, but then can be used in nearby boilers or furnaces, or in internal combustion engines and gas turbines.

In cases where the sale and/or use of coal mine gas would not be profitable or feasible, an alternative to utilization for mitigating coal mine CH_4 emissions is to destroy the CH_4 via flaring, thus converting the higher global warming intensity CH_4 into lower intensity CO_2.

Procedures to estimate CH_4 emissions from degasification will include estimating "emissions avoided." Estimating these "emissions avoided" has value in several respects. First, it provides a method for verifying emissions estimates for gassy mines. Second, it provides a mechanism for documenting current actions by operators to reduce emissions, even if these reductions were primarily implemented for safety, rather than GHG emissions reduction, reasons.

Emissions from post mining operations

Other sources of CH_4 emissions from the mining sector relate to activities after the coal is mined, and include coal piles and coal storage areas, coal transport operations, and the coal preparation plant. Estimated post-mining emissions accounted for 14% of all coal mining sector fugitive CH_4 emissions in 2006, representing 8.6 million metric tons of CO_2e. These emissions apply to both underground and surface coal mines. For these sources of fugitive emissions, emissions estimates are generally developed for emissions inventory purposes by using standard region or basin-specific emission factors, multiplied by rates of coal production, applied to all "post-mining" activities. Measuring and/or monitoring emissions from these operations would be difficult, since no robust monitoring methodology has been developed for these emissions. Moreover, existing emission factors are highly uncertain; and are established based on very sporadic data, if based on any emissions data at all.

One category of post-mining emissions that could be considered for monitoring is emissions from coal preparation plants. On April 16, 2008 (Federal Register: April 28, 2008, Vol. 73, No. 82, pp. 22901-22913), EPA proposed revisions to emissions control requirements for new coal preparation plants. These proposed new source performance standards (NSPS) would apply to new coal preparation plants that process more than 200 tons of coal per day. The proposed NSPS would apply to new, modified, and reconstructed coal preparation plants and reflect improvements in emission control technologies for particulate matter (PM) that have been developed since the original NSPS for these sources were issued in 1976.

As part of these new proposed NSPS requirements, EPA is proposing to require owners/operators of thermal dryers and pneumatic coal-cleaning equipment at constructed, modified, or reconstructed coal preparation plants to either install and operate a PM continuous emissions monitoring system (CEMS), or to conduct annual PM performance tests. A possible logical extension of this proposal would be to also include monitoring for fugitive CH_4 emissions from these coal preparation plants. For the installation of a new CEMS, the incremental costs of adding CH_4 monitoring capability to the PM monitoring capability would be relatively small, since the dual monitoring capability can be designed within the same system. Retrofitting after the fact to add CH_4 monitoring would cost more.

It is important to note that fugitive emissions from coal preparation plants represent a small portion of the total emissions from the coal mining sector. In fact, the vast majority of GHG emissions from a coal preparation plant correspond to the fuel consumed for various operations such as coal drying. Fugitive CH_4 emissions will only correspond to any remaining CH_4 emitted from the coal during processing.

Emissions from surface mines

Surface coal mines release CH_4 as the overburden is removed and the coal is exposed. The level of estimated emissions from surface mines is much lower than that from underground mines, representing 22% of all coal mine fugitive emissions, amounting to 14.0 million metric tons of CO_2e. Moreover, similar to that for post mining operations, emissions for surface mining are generally estimated for national inventory purposes by using standard region or basin-specific emission factors, multiplied by rates of coal production, applied to all surface mining activities. Monitoring emissions from these operations would be difficult, since; again, no robust facility-level methodology has been developed. Moreover, existing emission factors are highly uncertain; and are established based on very sporadic data, if based on any emissions data at all.

Emissions from abandoned mines

When coal mines are no longer operated to produce coal, they are known as closed or "abandoned" mines. Even though active mining no longer occurs, these abandoned mines can still produce CH_4 emissions from diffuse vents, fissures, or boreholes. This CH_4 can be deliberately extracted and used to generate power or for other end uses.

Methane liberated from abandoned mines is estimated to be 6.8 million metric tons of CO_2e per year, of which an estimated 1.4 million metric tons of CO_2e per year is recovered and used (EPA 2008). Therefore, an estimated 5.4 million metric tons of CO_2e is emitted per year, representing 8% of all fugitive CH_4 emissions from coal mines.

There are several thousand abandoned coal mines in the United States. Of these, EPA has identified some 400 abandoned mines that are considered "gassy," and has developed profiles of potential projects at abandoned mines that may be good candidates for project development (EPA 2004).

Measuring and/or monitoring emissions from abandoned mines would be difficult. There is currently no robust way to measure fugitive emissions from individual abandoned mines. Measuring at discrete borehole/wellhead sites would not adequately capture the emissions seeping out of various other fissures and leakage points. Moreover, in many cases, it can be quite difficult to identify owners of abandoned mine sites, i.e., it would be difficult to identify the responsible parties to monitor and report. Even where the owner is known, abandoned sites are unmanned and often remote; and it would be burdensome to require company personnel to travel to each abandoned mine site to measure emissions, along with being expensive and resource-intensive, especially given the relatively small contribution abandoned mines make to total GHG emissions in the coal mining sector.

ii) Combustion Emissions

Estimates of fuel consumption in the mining sector are reported by the Bureau of the Census (Census, 2004a, 2004b, 2004c, 2004d) for 2002, which include coal consumed directly in mining operations, distillate, residual fuel oil, natural gas, gasoline, and purchased electricity. The 2002 fuel consumption estimates were updated to 2006 based on 2006 levels of coal production, and based on this, an estimated 9 million metric tons of CO_2 emissions were associated with energy use in coal mining operations in the United States in 2006. The majority of these emissions result from the generation of electricity purchased to support mining operations. The CO_2 emissions from only on-site combustion (the value used in this analysis) are estimated to be 3.62 million metric tons.

2. Options for Reporting Thresholds

Several different thresholds were considered for CH_4 emissions from underground coal mines based on the data in MSHA databases, and the *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006* (EPA, 2008). The estimated emissions and facilities covered are summarized in Table 1 below for different emissions threshold levels, based on 2006 emissions levels.

<u>a. Options Considered</u>

5.1 Emissions-based thresholds

Data were collected and analyzed to evaluate several potential reporting thresholds. The primary options were based on the CH_4 liberated from mines:

i. An emissions threshold of 1,000 $mtCO_2e$
ii. An emissions threshold of 10,000 $mtCO_2e$
iii. An emissions threshold of 25,000 $mtCO_2e$
iv. An emissions threshold of 50,000 $mtCO_2e$
v. An emissions threshold of 100,000 $mtCO_2e$

5.2 Other threshold options

In general, MSHA samples (quarterly or more frequently) CH_4 emissions for mines liberating more than 100,000 cubic feet of CH_4 per day from ventilation systems,[2] which is equivalent to about 15,000 metric tons CO_2e per year. MSHA also samples methane from mines with special conditions, such as safety concerns. Of the over 600 underground coal mines operating in the U.S. according to EIA, ventilation air emissions based on MSHA inspections were reported and electronically accounted for in 128 mines in 2006.

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[2] Personal communication, Fred H. Menke, Jr., Supervisory IT Specialist, Mine Safety and Health Administration, to Michael Godec, Advanced Resources International, April 25, 2008.

Table 1
Threshold Analysis for Underground Coal Mining

Source Category	Threshold Level (Metric tons CO_2e per year)	Total National Emissions[a] (Metric tons CO_2e)	Number of Facilities[b]	Emissions Covered[c]				Facilities Covered	
				Process Emissions (Metric tons CO_2e/yr)	Estimated Combustion CO_2 Emissions (Metric tons/yr)	Metric tons (CO_2e/yr)	Percent	Number	Percent
Underground Coal Mining	100,000	39,520,000	612	30,649,815	405,040	31,054,856	79%	53	9%
Underground Coal Mining	50,000	39,520,000	612	32,316,726	438,262	32,754,988	83%	77	13%
Underground Coal Mining	25,000	39,520,000	612	33,082,854	453,531	33,536,385	85%	100	16%
Underground Coal Mining	MSHA quarterly reporting threshold	39,520,000	612	33,364,265	459,140	33,823,404	86%	114	19%
Underground Coal Mining	10,000	39,520,000	612	33,465,371	461,155	33,926,526	86%	122	20%
Underground Coal Mining	1,000	39,520,000	612	33,483,922	461,524	33,945,446	86%	125	20%

[a] Estimated national fugitive CH_4 emissions for underground mining from 2006 Annual Inventory (Table 3-26) (http://epa.gov/climatechange/emissions/downloads/08_Energy.pdf); plus estimated combustion emissions of 3.62 million metric tons, excluding those associated with purchased electricity.
[b] Number of active underground coal mines in the U.S. in 2006 according to the Energy Information Administration (EIA 2007).
[c] Based on the fugitive CH_4 emissions volumes reported for individual mines in the MSHA database "Analysis of 2006 Emissions Data for Active Underground Mines," along with estimated combustion-related emissions from these mine sites, but not including emissions associated with purchased electricity.
Estimates made for fuel combustion emissions based on Bureau of Census data on fuel use as a % of coal mined (for gassiest mines) or as % of vented emissions for less gassy mines. Combustion emissions calculated as approximately 1% to 3% of vented emissions, on CO_2e basis.

b. Emissions and Facilities Covered Per Option

CH_4 emissions from the 114 of the 128 underground coal mines reporting ventilation emissions in 2006 of over approximately 15,000 metric tons of CO_2e per year (equivalent to the current MSHA threshold for accounting for emissions from gassy mines) accounts for 86% of the 39.5 million metric tons estimated to be emitted by underground coal mines (35.9 million metric tons from CH_4 emissions and 3.6 million metric tons from combustion emissions, excluding those emissions associated with purchased electricity). These 114 mines represent 19% of the active underground mines in the United States. Increasing the reporting threshold to 25,000 metric tons of CO_2e per year would reduce the number of reporting mines by 14 to 100 and would reduce the amount of total emissions reported from this sector by 3%. If no threshold is established, and all mines must report, this will add nearly 500 mines to the number required to mines would only represent another 14% of the total GHG emissions from underground coal mines.

Other options for establishing thresholds could be based on other factors, such as coal production. An option using coal production as a threshold was considered, but not proposed because coal production is not closely correlated to CH4 liberation. Alternative threshold levels for reporting could also be considered. However, thresholds for and procedures for sampling CH4 liberation above defined levels are already established by MSHA, utilizing this threshold is the most logical and least burdensome method for establishing GHG monitoring and reporting thresholds for the coal mining sector, while capturing a majority of GHG emissions from the sector.

3. Existing Relevant Reporting Programs/Methodologies

For this proposal, EPA reviewed several protocols and programs with guidance monitoring and/or estimating GHG from this source, including the 2006 IPCC GL, U.S. GHG Inventory, California AB32 ("CARB rule"), EIA's 1605(b) program, EPA's Coalbed Methane Outreach Program (CMOP), MSHA, BLM, and Australia's National Mandatory GHG Reporting Program (draft).

In general, there are three methods for monitoring emissions: the use of emission factors, periodic sampling of CH_4 concentrations and flow, and direct measurement.

This section presents the existing relevant monitoring methods by coal mine CH_4 sources.

Underground mines – mine ventilation

MSHA regulatory requirements specify that qualified and trained MSHA field inspectors perform periodic mine safety inspections at all underground coal mines in the United States, and as part of these inspections, test CH_4 emissions rates at each coal mine according to MSHA-approved sampling procedures.[3] Air sampling is conducted by MSHA inspectors collecting air bottle samples at a mine's main fans, along with a total quantity air ventilation volume reading. Sampling procedures and equipment are approved by MSHA (NIOSH 2006). The sample bottles are sent to the MSHA lab for analysis and the results are provided back to the MSHA district offices for inclusion in the inspection report. The results are also maintained separately by the district ventilation group.

In general, air sample readings with CH_4 concentrations below 50 ppm are considered non-detectable. Air samples and ventilation readings are taken annually unless CH_4 emission rates exceed 100,000 standard cubic feet per day, where quarterly sampling is then conducted. MSHA electronically keeps track of emissions for mines liberating more than 100,000 cubic feet of CH_4 per day,[4] which is equivalent to about 15,000 metric tons CO_2e per year. If emissions levels are greater that 200,000 cubic feet per day, according to Section 103 (i) of the Federal Mine Safety

[3] MSHA requires that monitoring be performed by a qualified person using CH_4 monitoring devices approved by MSHA (under 30 CFR Parts 18,21,22,23,27, and 29); and that are maintained in permissible and proper operating condition and calibrated with a known CH_4-air mixture at least once every 31 days.
[4] Personal communication, Fred H. Menke, Jr., Supervisory IT Specialist, Mine Safety and Health Administration, to Michael Godec, Advanced Resources International, April 25, 2008.

& Health Act of 1977 (Public Law 95-164), more frequent inspections are mandated, with the frequency determined by the daily CH_4 liberation rate calculated for the mine.

For the mines with emissions exceeding 100,000 cubic feet per day, annual ventilation emissions estimates are developed by averaging the four quarterly tests, and are accurate to the extent that the data collected are representative of actual emissions.

In addition, for federal coal leases where degasification systems are in place, the Bureau of Land Management (BLM) requests that mine operators provide CH_4 emissions rates from both degasification and ventilation systems to BLM. Operators currently provide this information voluntarily; it is not a requirement either by regulation or under their federal coal lease terms.[5]

For this source, the IPCC Guidelines recommend that where mine-specific measurement data are available, it is good practice to use a method comparable to that based on the MSHA sampling results. In situations when mine-specific measurement data are available only for a subset of underground mines (which generally should not be the case in the United States), the Guidelines specify that emissions from the remaining mines can be calculated with emission factors based on the mines with measurement data. These emission factors can be based on specific emission rates derived from operating mines within the same basin, or on the basis of mine-specific properties, such as the average depth of the coal mines. When no mine-specific data are available, but country- or basin-specific data are, the IPCC Guidelines suggest that it is good practice to employ a Tier 2 method. Where no data (or very limited data) are available, the Guidelines specify that it is good practice to use a Tier 1 approach, provided underground coal mining is not a key sub source category.

To calculate emissions from ventilation at underground mines in the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (EPA, 2008), EPA uses the IPCC guidelines, and CH_4 emissions data collected through the MSHA sampling program process, which also serves as the basis for EPA's CMOP emissions estimates from this source.

DOE 1605(b) inventory reporting guidelines specify that mines with undetectable CH_4 levels can calculate ventilation emissions by multiplying a flow rate of 3,000 cubic feet per minute by an assumed CH_4 concentration of 0.05% to derive a CH_4 emissions rate (DOE 2007). DOE 1605(b) guidelines otherwise provide the same methodology as the *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (EPA, 2008) and IPCC.

Australia's National Mandatory GHG Reporting Program (draft) (Australia 2008) recommends a methodology comparable to that in the 2006 IPCC Guidelines.

Recent draft reporting regulations proposed by the California Air Resources Board (CARB 2008) do not prescribe any approach for estimating emissions from coal mining operations; these only propose the use of emission factors to estimate emissions from post-mining coal storage and handling activities (see discussion below).

Underground mines – degasification

As discussed above, of the 20 U.S. coal mines deploying degasification systems in 2006, 13 mines sent this gas to a pipeline. It is common practice for these mines to monitor the volume of gas produced and delivered to the pipeline (which also monitors these volumes). Coal mines

[5] Personnel communication, Desty Dyer, U.S. Bureau of Land Management (BLM), Montrose Field Office, to Michael Godec, Advanced Resources International, Inc., June 6, 2008

using CH_4 from degasification systems on site to heat mine ventilation air are also likely to monitor the volumes of CH_4 produced.

In contrast to CH_4 emissions from ventilation systems, no agency requires mines to report the amount of CH_4 they drain from degasification systems. MSHA collects information about the presence and type of degasification systems in some mines, but does not collect quantitative data on the amount of CH_4 liberated. As mentioned above, BLM requests that mine operators on federal coal leases provide information on CH_4 emissions from both ventilation and degasifications systems. Most mines do provide degasification information voluntarily to CMOP.

As part of the annual U.S. inventory, EPA estimates the volume of CH_4 drained assuming drainage efficiencies based on information obtained from MSHA district offices or from information provided by operators. Some of the coal mines employing degasification systems have provided EPA with information regarding CH_4 liberated from their degasification systems. In cases in which mines sell CH_4 recovered from degasification systems to a pipeline, gas sales are used to estimate CH_4 liberated from degasification systems. For those mines that do not sell CH_4 to a pipeline and/or do not currently provide information to EPA, CH_4 liberated from degasification systems is estimated by EPA based on the type of system employed. For example, for coal mines employing gob wells and horizontal boreholes, the methodology assumes that CH_4 volumes liberated from degasification systems account for 40% of total CH_4 liberated from the mine. This is also the recommended method presented in the DOE 1605(b) Guidelines.

The IPCC Guidelines suggest a similar approach. Where ventilation can be measured (or can be estimated from measurements from similar mines in the same basin or region), but not degasification volumes, they suggest that reporters estimate the amount degasified (although no methodology is specified) and use appropriate methods for accounting for the disposition of the degasified CH_4 (e.g.; vented, flared, sold, consumed on-site). Several suggested approaches are provided in the Guidelines. Australia's National Mandatory GHG Reporting Program (draft) (Australia 2008) recommends a methodology comparable to that in IPCC Guidelines.

Post mining operations

For post-mining operations, since mine-specific emissions measurements are not available, emissions estimates for the U.S. inventory are developed by using basin-specific coal production multiplied by a basin-specific emission factor. Emission factors for surface mined coal were developed from the in situ CH_4 content of the surface coal in each basin. Furthermore, the post-mining emission factors used were estimated to be 25 to 40% of the average in situ CH_4 content in the basin. Thus, for the current inventory, the post-mining emission factor was determined to be 32.5% of the in situ CH_4 content in the basin.

The IPCC Guidelines and the DOE 1605(b) guidelines also recommend this approach for inventory development purposes, and CARB recommends this approach (for coal storage) as part of its mandatory greenhouse gas reporting program. Australia's National Mandatory GHG Reporting Program (draft) (Australia 2008) recommends a methodology comparable to that in IPCC Guidelines.

Surface mines

Similarly, surface mining emissions estimates for the U.S. inventory are also developed by using basin-specific coal production multiplied by a basin-specific emission factor. Emission factors for surface mined coal were developed from the in situ CH_4 content of the surface coal in each basin. Surface mining emission factors were estimated to be from 1 to 3 times the average in situ CH_4 content in the basin. For the current inventory, the surface mining emission factor was determined to be twice the in situ CH_4 content in the basin.

Again, the IPCC Guidelines and the DOE 1605(b) guidelines also recommend this approach for inventory development purposes, as does Australia's National Mandatory GHG Reporting Program (draft).

Abandoned mines

EPA (EPA 2004) and the IPCC (IPCC 2006) have developed emissions estimation methodologies for abandoned underground mines for emissions inventory purposes. EPA developed emissions estimation methodologies for abandoned or closed underground mines for emissions inventory purposes based on the time since abandonment; gas content and adsorption characteristics of the coal, CH_4 flow capacity of the mine; mine flooding; the presence of vent holes, and mine seals. The IPCC methodology is based on the elapsed time since abandonment, the mine's initial gassiness, and the extent to which the mines have become flooded.

Australia's National Mandatory GHG Reporting Program (draft) (Australia 2008) recommends a methodology comparable to that in IPCC Guidelines.

DOE 1605(b) guidelines contain no specific recommendations for estimating emissions from abandoned coal mines.

4. Proposed Monitoring Methods

a. Monitoring Methods Considered

Emissions in Ventilation Air

i. Option 1: Continuous Monitoring

The direct measurement option considered would involve implementing continuous monitoring systems in underground coal mine ventilation shafts. This option builds upon the fact that continuous monitors are already in place throughout all underground coal mines. For compliance with this GHG emissions monitoring rule, such monitoring devices could be placed at or near the mine vent outflows where the air samples are taken by MSHA inspectors.

Federal safety standards[6] mandate that, "when 1.0 percent or more CH_4 is present in a working place or an intake air course […] electrically powered equipment in the affected area shall be de-energized, and other mechanized equipment shall be shut off." A flammable mixture of CH_4 and air can be ignited by electric arcs and sparks, open flames, or by the heat of friction between the cutting bits of mining equipment and the mine rock immediately above or below the coal.

To ensure that CH_4 levels in underground coal mines remain below combustible levels, continuous monitoring devices are in operation within underground coal mines. MSHA regulations require that wall and/or machine-mounted CH_4 monitors are mounted at various locations and on certain types of machinery to continuously monitor mine air quality. These

[6] Code of Federal Regulations, Title 30, Part 75: Mandatory safety standards--underground coal mines

monitors are certified under 30 CFR Part 27,[7] which requires monitoring system design and operation that prevents the mining equipment from operating unless the CH_4 monitoring system is functioning. The CH_4 monitoring system has a warning device that activates when the CH_4 concentration is above 1.0% to 1.5%, and has a means to shut off power to the equipment when the CH_4 concentration is above 2.0%.

Methane detectors fall into two categories: portable CH_4 detectors and wall or machine-mounted monitors. Most CH_4 detectors used in mining use a catalytic heat of combustion sensor to detect CH_4 and other combustible gases. These have been proven reliable through many years of operation. For detection of CH_4, proper operation of catalytic heat of combustion sensors requires both a CH_4 concentration below 8% (by volume) and oxygen content above 10% -- requirements that are usually satisfied in mining applications.

Some detectors measure the CH_4 concentration by using infrared absorption as an operating method. These infrared detectors can measure accurately without oxygen and at concentrations up to 100% CH_4. However, water vapor and dust can cause operating difficulties. In some mines, the CH_4 may be accompanied by ethane, which can produce an exaggerated infrared detector response.

Machine-mounted CH_4 monitors are usually mounted on mining and tunnel-boring machines. They are designed to have their readout display separated from the sensing head so that the readout is visible to the machine operator and the sensing head is placed in a location where CH_4 is most likely to accumulate. Machine and wall-mounted monitors operate continuously and can identify emission peaks. Using machine or wall-mounted monitors could likely improve the accuracy of emissions measurements in underground mines, when operated and calibrated properly, compared to periodic sampling. The resolution of these monitors can be specified – in general, the higher the resolution, the higher the cost. Resolutions at levels lower than the 50 ppm limit, which characterizes the current MSHA sampling protocol, are certainly achievable. Nonetheless, emissions at levels below the resolution of the monitors, if assumed to be zero could correspond to an underestimation of emissions.

The advantage of continuous monitoring is that it takes into consideration any variability in emissions from mining operations that may not be represented in periodic sampling. Moreover, since such devices are already used within the mine, mine operator personnel are familiar with their operation.

A disadvantage would be the larger costs associated with purchasing and maintaining these continuous emissions monitoring systems (CEMS) devices for this application.

ii. Option 2: Quarterly Sampling of CH_4 Content and Gas Flow

Under this option, coal mine operators would be required to duplicate the MSHA process of collecting air samples and ventilation rates, submitting the samples to a lab for analysis, and developing estimates of emissions on their own. This would require mine operators to purchase sampling equipment, train personnel in their use, develop emissions estimates based on the data collected, and report the results. If this option is pursued, the operator would have to incur the capital and O&M costs involved in purchasing and maintaining the air sampling equipment, and in sending air samples to an independent lab for analysis.

[7] A list of approved gas monitors for U.S. mines is available from MSHA's Approval and Certification Center (http://www.msha.gov/TECHSUPP/ACC/lists/27mthmon.pdf)

Alternatively, the results of MSHA inspections could be used to estimate ventilation air emissions. In this case, mines would obtain data from MSHA (it is not currently shared with the mine). An advantage of MSHA sampling and reporting is that MSHA inspectors have procedures in place, and a high level of QA/QC is established for this process. Minimal additional training of operator personnel would be required, the implementation period could be almost instantaneous, and the accuracy of emissions estimates would most likely be higher.

iii. Option 2: More Frequent Sampling

Sampling could be done more frequently than quarterly. This could provide a more consistent, reliable, and representative characterization of fugitive CH_4 mine emissions, but at a higher cost.

iv. Option 3: Simplified Emission Calculation

This option would involve utilizing the same procedures as recommended by the IPCC and DOE 1605(b) Guidelines, assuming no mine-specific data were available. For inventory reporting purposes, the IPCC Guidelines recommend that when ventilation emissions cannot be measured, they can be estimated from measurements from similar mines in the same basin or region. If analogous mine-specific data are unavailable, they recommend using basin/region-specific emission factors multiplied by production, and representative emissions factors are provided in the Guidelines.

Degasification Systems

(i) Option 1: Continuous Monitoring

This option involves continuous monitoring of gas recovered from mine degasification systems. This option would apply to all degasification wells, including gob gas vent holes and other degasification wells that are currently not monitored.

Approaches for monitoring the volumes of CH_4 produced from coal mine degasification systems prior to mining use the same general techniques for monitoring gas flows from natural gas production wells. Recommendations for improved approaches for both degasification systems and monitoring gas flow specifically from degasification wells date back to the mid-1970s (Lambert and Trevits, 1978; Diamond, 1994). Degasification systems operate in conjunction with the ventilation system and overall mining operations, generally requiring coordinated management (using measuring instruments, monitoring, controls, and good communications) to optimize overall operations.[8]

The advantages to this approach are that continuous monitoring provides accurate data and can captures seasonal changes in gas flow and concentrations, and that most degasification systems where the produced CH_4 is sold or used on site for energy generally already have continuous monitoring in place. The disadvantage would be the costs incurred by mines that do not currently have these systems in place, and the infeasibility of installing and maintaining monitors at all degasification sites, some of which are in remote and inaccessible locations.

ii) Option 2: Sampling of CH_4 Content and Gas Flow

This option would involve continuous monitoring for those wells already deploying such systems, but would allow periodic sampling for those that do not. For example, gob gas vent holes that are currently not monitored could conduct periodic sampling, as could perhaps any

[8] http://www.epa.gov/cmop/docs/ggasrecpv.pdf

other degasification borehole, rather than installing continuous monitoring. For example, weekly or monthly sampling at each gob gas vent hole/well could be conducted. While such an approach would involve less capital costs, greater labor costs would be involved with traveling to each (often remote) well/vent site to take samples.

If direct measurements of gas volumes are not available for degasification wells, other options could be to: (1) use gas sales data, and/or (2) apply an assumed degasification efficiency based on the technology used. This is the procedure suggested in the IPCC and DOE 1605(b) Guidelines, and is the method currently used in the U.S. inventory if underground coal mine degasification volumes are not available. For example, for coal mines employing gob wells and horizontal boreholes, the methodology assumes that degasification emissions account for 40% of total CH_4 liberated from the mine. Gas sales data, if available, would be a direct proxy for the volume of methane produced from degasification systems, and is more accurate than an assumed degasification efficiency. While simple in application, the use of an assumed degasification efficiency is highly uncertain, since such an efficiency is clearly a function of many mine-specific parameters that can vary considerably from mine-to-mine.

Option 3: Simplified Emission Calculation

This option would involve utilizing the same procedures as recommended by the IPCC and/or DOE 1605(b) Guidelines, assuming no mine-specific data were available. For GHG inventory reporting purposes, the IPCC Guidelines recommend that when recovered gas from degasification systems cannot be measured, they can be estimated from measurements from similar mines in the same basin or region. If analogous mine-specific data are unavailable, they recommend using basin/region-specific emission factor multiplied by production, and representative emissions factors are provided in the Guidelines. Again, similar to that discussed above, while simple in application, the use of simplified emissions calculation approach is highly uncertain, since emission are a function of many mine-specific parameters that can vary considerably from mine-to-mine.

Methane Combustion at Ventilation or Degasification Systems

(i) Option 1: Continuous Monitoring

This option involves continuous monitoring of the disposition of gas recovered from coal mines. Although this measurement is continuous, reporting would only be annual. This option would apply to all combustion sites, including those occurring at gob gas vent holes and other wells that are currently not monitored.

Approaches for monitoring the volumes of CH_4 combusted are generally well established. Many mines already monitor the amount of CH_4 liberated from coal mine degasification that is combusted on site.

The advantages to this approach are that continuous monitoring provides accurate data and can captures seasonal changes in gas flow, concentrations, energy use, and combustion efficiencies, and that most degasification systems already have continuous monitoring in place. The disadvantage would be the costs incurred by mines that do not currently have these systems in place.

(ii) Option 2: Simplified Combustion Calculation

This option would involve utilizing the same procedures as recommended by the IPCC and/or DOE 1605(b) Guidelines, assuming no mine-specific data were available. For GHG inventory reporting purposes, the IPCC Guidelines recommend that when combusted gas cannot be measured, simple combustion calculations be used.

5. Procedures for Estimating Missing Data

Options and considerations for missing data vary will vary depending on the proposed monitoring method. In general, each option would require a complete record of all measured parameters and parameters determined from company records that are used in the GHG emissions calculations (e.g., carbon contents, monthly fuel consumption, etc.). Therefore, whenever a quality-assured value of a required parameter is unavailable (e.g., if a monitor or CEMS malfunctions during unit operation or if a required fuel input parameter is not obtained), a substitute data value for the missing parameter must be used in the calculations.

In addition, since periodic inspections are performed on all underground coal mines, data on CH_4 concentrations (above 50 ppm) and ventilation rates exist for all mines. For mines below the 50 ppm "detectable" threshold, estimates could be made for emission rates assuming some value for CH_4 concentrations (say 25 ppm). However, it again should be emphasized that the vast majority of emissions from underground coal mines come from roughly 1/6 of the gassiest underground coal mines.

For emissions avoided from degasification systems, methods are described above for estimating volumes for CH_4 recovered (Option 3) should recovered volumes not be known.

For missing gas flow or gas recovery data, the substitute data value could be the arithmetic average of the quality-assured values of that parameter immediately preceding and immediately following the missing data incident. If, for a particular parameter, no quality-assured data are available prior to the missing data incident, the substitute data value shall be the first quality-assured value obtained after the missing data period.

EPA considered not deducting CH_4 combustion that was not recorded, but not including CH_4 recovery could greatly overestimate a facility's emissions. On the other hand, allowing extended periods of missing data provides a disincentive to repairing the monitoring system.

6. QA/QC and Verification Requirements

In addition, mines should conduct quality assurance and quality control of emission estimates reported. Facilities are encouraged to prepare an in-depth quality assurance and quality control plan which would include checks on the data collected, and the calculations performed to estimate GHG emissions.

MSHA has established specific regulatory requirements for maintaining and ensuring the accuracy of mine sampling processes and for the operation of in-mine monitors. In particular, 30 CFR Part 75 specifies requirements for the maintenance and use of in-mine CH_4 monitors and for portable air quality detectors and measurement devices. The section also sets forth requirements for ensuring that MSHA inspectors are trained and certified to take samples, and operators responsible for in-mine monitoring systems must also be certified.

Similarly, since they are used to register volumes for gas sales, existing monitors for measuring gas produced from degasification systems are considered to be accurate, and both sellers and buyers of the gas produced have a vested interest in ensuring that the volumes recovered are accurate.

7. Reporting Procedures

For underground coal mines, the issues to consider with regard to reporting relate both to the party responsible for reporting emissions to EPA, and to the frequency of reporting. In the case of the reporting party, options to consider include whether MSHA does the reporting to EPA (of emissions from ventilation systems), or if the operator should be responsible for reporting.

Recovered CH_4 volumes from degasifications systems (emissions avoided) will be reported by the operator.

In terms of frequency, options considered include annual, quarterly, and, perhaps, even more frequent reporting.

The issues (other than frequency, as noted above) to consider are somewhat different for reporting of emissions from ventilation systems or emissions avoided from degasification systems, so each of these two areas are discussed separately below.

Emissions in Ventilation Air

With regard to mine CH_4 ventilation emissions, the information currently collected by MSHA (CH_4 concentration, ventilation flow rates, major changes in mine activity, etc.) should be sufficient to support implementation of Options 2, 3, or 4, discussed above. However, current CH_4 emissions data collection and reporting are conducted by MSHA field inspectors, with the results reported to and maintained by MSHA district offices. In general, mine operators are currently not provided a copy of the results of the sampling or the estimates made for CH_4 emissions, unless emission levels are of concern to MSHA.

As discussed above, MSHA currently voluntarily provides EPA with its mine-by-mine estimates of annual CH_4 emissions for the gassiest mines. This provides the basis for both EPA's estimates of coal sector emissions in the national inventory (EPA 2008), as well as providing the Coalbed Methane Outreach Program (CMOP) its basis for identifying opportunities for CH_4 recovery at U.S. coal mines (EPA 2005). However, in developing its annual emission estimates, MSHA develops these estimates by averaging the sample data results from quarterly inspections.

Several options are available for reporting the results of GHG emissions monitoring in the coal mining sector. These are:

- MSHA continues to collect ventilation air samples and rates, and from these develop estimates of GHG emissions for all mines that exceed a defined CH_4 emissions threshold (currently 100,000 cubic feet per day). Then, MSHA would be responsible for reporting CH_4 emissions estimates directly to EPA. Under this option, the incremental burden on both coal mine operators and MSHA would be small.
- MSHA continues to collect ventilation air samples and rates, and from these develop estimates of GHG emissions for all mines that exceed the defined CH_4 emissions threshold. Then, MSHA would make these emissions estimates available to mine operators, and the operators would be responsible for reporting emissions levels to EPA. Under this option, the burden on MSHA would be the same – it would now just provide

its emissions estimates back to the operator, rather than EPA. In this case, the burden on the operator would be greater, since it would now need to report to EPA.

- MSHA would continue to collect ventilation air samples and rates, but provide just the sampling results to the operator, and the operator would develop its own estimates of GHG emissions from these sample results, and report emissions estimates to EPA. Here, the burden on MSHA would actually be reduced somewhat from the above options (though it would still need to send the operators the sampling results), but the burden on the operator would be considerably greater.
- Coal mine operators would duplicate the MSHA process, by collecting air samples and ventilation rates, submitting the samples to a commercial lab for analysis, developing estimates of CH_4 emissions, and reporting this information to EPA. This would impose a burden on the operators.

Currently, although MSHA collects samples quarterly for the gassy mines, emissions estimates are only developed on an annual basis. If quarterly reporting is implemented, this would require that MSHA develop quarterly, rather than annual, CH_4 emissions estimates, and report these either to EPA or to the mine operator.

If mine air ventilation emissions are monitored using a CEMS, the operator would be responsible for reporting, at the frequency specified (annual, quarterly, etc.).

Under any of the reporting options, it would also be expected that operators should also report any CH_4 emissions from ventilation air that are destroyed or utilized. This data is presumably automatically collected by the installed equipment. It is also recommended that operators report the number of days in a quarter that the mine is shut down.

Degasification Systems

With regard to coal mine degasification systems, even when continuous monitoring of CH_4 recovered from degasification systems, reporting is done on an annual or quarterly basis. Operators would be responsible for reporting the volumes of CH_4 recovered from these systems, along with the disposition of the CH_4 (sold, used on site, and/or destroyed/flared. Reporting would be directly to EPA.

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