

Coal Mine Methane Recovery

Goal:

Encourage owners/operators of current longwall mines, and of any new gassy underground coal mines that are mined by any method, to capture 10% of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations

Initiative Background:

The release of methane gas to the atmosphere is a major component of Greenhouse Gas emissions. Methane gas is a fossil fuel and energy source, commonly known as natural gas, which occurs in various geologic formations in Pennsylvania, including coal formations. When coal is mined and processed for use, substantial amounts of methane gas are released. Coal bed methane (CBM) is methane contained within coal formations and may be extracted by gas exploration methods or released as part of coal mining operations. This work plan deals with coal mine methane (CMM), the methane within the coal that can be vented or recovered prior to mining the coal, during mining, and immediately after mining as some gas escapes to the surface through post-mining vents or boreholes. Methane gas that remains sequestered within an abandoned underground coal mine does not contribute to Greenhouse Gas emissions, but could be and sometimes is recovered by subsequent gas exploration operations.

The federal Mine Safety and Health Administration (MSHA) definition of a gassy mine, as defined in 30 CFR § 27.2 (g), is that a “*Gassy mine or tunnel* means a mine, tunnel, or other underground workings in which a flammable mixture has been ignited, or has been found with a permissible flame safety lamp, or has been determined by air analysis to contain 0.25% or more (by volume) of methane in any open workings when tested at a point not less than 12 inches from the roof, face, or rib.” MSHA records coal mine methane readings with concentrations of greater than 50 parts per million (ppm) methane. Readings below this threshold are considered non-detectable.

Currently and in recent years approximately 85% of the methane gas released during the mining of coal in Pennsylvania occurs from mining in longwall underground mines. The five large longwall underground coal mines now operating in Pennsylvania extract approximately 60% of the 68 million tons of coal mined each year within Pennsylvania. These high amounts of longwall mine production and the fact that the longwall mines recover coal from greater depths than other mines make longwall mining the predominant current source of coal mine methane release and an important contributor to Greenhouse Gas emissions. In recent years several mining companies have begun to capture and utilize methane gas within longwall underground mines, resulting in a reduction of methane Greenhouse Gas emissions.

Surface mining of coal currently releases about 9% of all coal mine methane emissions in Pennsylvania. However, with the continuing decline in surface mining production as recorded over the past two decades and the ultimate depletion of the state’s shallow coal reserves, it is possible that by 2025 there could be a 70% reduction of surface coal mine methane emissions simply as a result of lower production.

Possible New Measures:

Surface Mines and Non-gassy Underground Mines

There are no specific measurements of methane gases released from mining at individual surface coal mines in Pennsylvania. This analysis uses the most recently published U.S. EPA emission factors for surface mining of coal in Pennsylvania. In this analysis the same emission factors used for surface mines are also used for low-methane non-gassy room and pillar underground coal mines. These are underground coal mines that have no methane levels routinely reported by MSHA. The U.S. EPA emission factor is 119.0 cubic feet of methane released per ton of coal mined and an additional 19.3 cubic feet of methane released from post-mining processing of the coal. These factors are published within Annex 3 Section 3.3 “*Methodology for Estimating CH₄ Emissions from Coal Mining*” of the U.S. EPA report “*Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2007*,” published April 15, 2009, as document EPA 430-R-09-004, and is available on the Internet at the website:

<http://www.epa.gov/climatechange/emissions/usinventoryreport.html>

Gassy Underground Mines

Methane levels reported by MSHA for gassy underground mines indicate two basic categories: gassy room and pillar mines and gassy longwall mines. Emission factors developed for these two types of gassy underground mines represent an estimate of the total methane released from the entire mining process, including pre-mining degassing and post-mining venting, as well as that liberated by ventilation systems. For both types of gassy underground mines this analysis uses the U.S. EPA emission factor of 45.0 cubic feet of methane per ton of coal to account for methane released as a result of post-mining processing of the coal on the surface. This post-mining factor is published in the 2009 EPA Report referenced previously. The total emission factor used for gassy room and pillar underground mines is 165 cubic feet of methane per ton of coal mined and processed on the surface. During the past few years, approximately 20% of Pennsylvania’s room and pillar mines have been gassy, with these mines accounting for approximately 33% of the total coal production from room and pillar mines. The average methane concentrations reported for these mines during the past few years, when compared to tons of coal mined, is 120 cubic feet of methane per ton of coal mined. Room and pillar underground mines were assumed, on average, to operate 310 days per year and longwall mines to operate 330 days per year. These emission factors represent an estimate for all methane released before, during, and after the mining of coal in these gassy underground mines. The total longwall underground mine emission factor is 445 cubic feet of methane per ton of coal mined and processed on the surface. Estimates of coal mine methane released during longwall mining are based on methane liberation and capture measurements, on horizontal degassing and capture measurements, and on pre-mining and post-mining surface drill hole degassing measurements recorded and provided by the coal industry and by MSHA. These methane concentration measurements were correlated with tonnages of coal mined. The average coal mine methane emission level reported for the five active longwall mines, when compared to tons of coal mined, is 400 cubic feet of methane per ton of coal mined. This is an average of measurements made over several years. CONSOL provided data for three longwall mines for the years 2000 through 2006 and Foundation Coal provided data for two longwall mines for the years 2004 through 2008.

This Coal Mine Methane Recovery Initiative would encourage owners/operators of current longwall mines, and of any new gassy underground coal mines that are mined by any method, to capture 10% of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations. At this time it is not feasible to capture methane liberated by high velocity ventilation systems, therefore the proposed and encouraged 10% capture of total coal mine methane from gassy underground coal mines would have to be realized from pre-mining surface drill holes, horizontal drill holes within the mine, or for a brief time from surface drill holes into the post-mining gob area.

Quantification Approach and Assumptions:

Estimates of methane emissions, expressed in thousand cubic feet (Mcf), are converted to carbon dioxide equivalents (CO₂e) by multiplying the quantity of methane times its global warming potential of 21. One million cubic feet of methane is equal to 404.5 metric tons of CO₂ equivalent.

The following inputs were used in the analysis of coal mine methane GHG reductions and costs. Three cost & performance sensitivities were conducted (the summary table only reports the central estimate).

PA specific data inputs were used for the following parameters

- Coal mining emissions for longwall mining (ft³ CH₄ per ton coal mined)
- Number of CONSOL's PA longwall mines
- Gob gas production shares from CONSOL's and Alpha Coal longwall mines
- Methane capture target from longwall mines

National data inputs were used for the following parameters:

- Natural gas Henry Hub wellhead price projections for the Lower 48 states, reported by (EIA), ranging from \$3.97/MMBtu in 2013 to \$4.39/MMBtu in 2020
- Financial parameters include a project life time of 20 years, 5% discount rate and 8.02% capital cost recovery factor
- Projected coal production is based on historical PA production multiplied by an average national growth trend, as provided by EIA in the Annual Energy Outlook 2012

Projected 2020 Reduction (Million Metric Tons of CO₂ Equivalents):

Concentrations of released methane are expressed as cubic feet per ton (2,000 lbs) of coal mined. One million cubic feet of methane is equal to 404.5 metric tons of CO₂ equivalent greenhouse gas. Estimates of coal mine methane released during mining are based on methane liberation and capture measurements recorded and provided by the coal industry and by the federal Mine Health and Safety Administration (MSHA), and on emission factor estimates published in the 2009 U.S. EPA report "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007." For all types of coal mines, the release of methane determined and predicted in this analysis is expressed as cubic feet of methane per ton of coal mined. Total annual methane concentrations are also expressed as metric tons of CO₂ equivalent.

Coal mine production for the years 1985 through 2010 was used to develop a trend analysis that was used to determine 2020 estimates. Production data reflects actual tonnages reported quarterly and annually to the Pennsylvania DEP Bureau of Mining and Reclamation. Coal production information is available to the public for the years 1980 through 2010 at the following website: <http://www.coalmininghistorypa.org> Trend charts for annual coal production and mining permits issued are presented at: http://www.coalmininghistorypa.org/annualreport/2010/Coal_Mining_Trend_Charts_001.htm

As illustrated in Table 1, in Year 2000 estimated GHG emissions from coal mining activity in Pennsylvania were 1.33 million metric tons CO₂ equivalent (MMtCO₂e). Future emissions are expected to drop commensurate with projected decreases in coal mining activity. Table 2 shows that in 2020, GHG emissions are estimated at 1.29 MMtCO₂e, a 3% decrease. This baseline value assumes no methane capture is in place. In contrast, if the 10% goal of this work plan is achieved the resultant emissions are estimated to be 1.18 MMtCO₂e, a decrease of approximately 12% from the Year 2000 baseline, as noted in Table 3.

Table 1. Summary of Estimated Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2000 Levels, No Methane Capture

	Methane Emission Factor (ft³/t)	Coal (tons)	Methane (Cubic Feet)	MMtCO₂e
Anthracite Underground Mines	138.3	220,462	30,489,895	0.00
Anthracite Surface Mines	138.3	2,332,828	322,630,112	0.02
Bituminous Surface Mines	138.3	15,024,529	2,077,892,305	0.11
Room & Pillar Bituminous Underground Mines		18,929,625		
Room & Pillar Mines with Low Methane	138.3	12,682,848	1,754,037,945	0.09
Room & Pillar Mines with High Methane	165	6,246,776	1,030,718,059	0.05
Longwall Bituminous Underground Mines	445	45,073,586	20,057,745,681	1.06
Totals for Coal Mining in Pennsylvania		79,027,739	25,273,513,998	1.33

*All methane emission factors include U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.

Table 2. Summary of Estimated and Projected Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2020 Levels with No Capture in Gassy Underground Mines

Mine Type	Methane Emissions Factor (ft³/ton)	Coal (tons)	Methane (ft³)	MtCO₂e	MMtCO₂e
Anthracite Mines (all), Bituminous Surface Mines, Room & Pillar Mines with Low Methane	138.3	10,534,267	1,456,889,103	169,547	0.17
Room & Pillar Mines with High Methane	165.0	1,208,049	199,328,060	23,197	0.02
Longwall Bituminous Underground Mines	445.0	21,177,268	9,423,884,337	1,096,714	1.10
Totals for Coal Mining in Pennsylvania		32,919,584	11,080,101,500	1,289,458	1.29

*All methane emission factors include U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.

Table 3. Summary of Estimated and Projected Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2020 Levels with 10% Methane Capture in Gassy Underground Mines

	Methane Emissions Factor (ft³/ton)	Coal (tons)	Methane (ft³)	Capture Efficiency	MtCO₂e	MMtCO₂e
Anthracite Mines (all), Bituminous Surface Mines, Room & Pillar Mines with Low Methane	138.3	10,534,267	1,456,889,103	0%	169,547	0.17
Room & Pillar Mines with High Methane	165.0	1,208,049	199,328,060	10%	20,877	0.02
Longwall Bituminous Underground Mines	445.0	21,177,268	9,423,884,337	10%	987,043	0.99
Totals for Coal Mining in Pennsylvania		32,919,584	11,080,101,500		1,177,467	1.18

*All methane emission factors include U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.

Economic Cost:

This initiative is cost-effective, as noted in Table 4. The analysis includes conservative estimations such as a methane concentration of only 50%, as compared modeled concentrations up to 90%, and for smaller units sized at 3million standard cubic feet (MMscf), as compared to larger units (4 MMscf and 5MMscf). The analysis assumes a parasitic load of 19% fuel consumption to power compressor equipment; less is needed for larger, more efficient units). Projections for Henry Hub natural gas well pricing was obtained from EIA Annual Energy Outlook 2012 to estimate sales revenue. These prices ranged from \$3.69 to \$4.280 per MMBtu. Capital costs are assumed to be \$5.46 million per unit, amortized over an assumed useful life of 20 years. A real discount rate of 5% is applied to annual costs. The applied capital recovery factor is 8.02%. The calculated net present value of this initiative reflects a cost savings of approximately \$234 million. The cost effectiveness is a savings of \$4,887 per ton of CO₂e reduced.

Implementation Steps:

This Coal Mine Methane Recovery Initiative would encourage owners/operators of current longwall mines, and of any new gassy underground coal mines that are mined by any method, to capture 10% of the estimated total coal mine methane that is released into the atmosphere before, during, and immediately after mining operations. This could be accomplished by pre-mining gas exploration into the coal formation to be mined, capturing methane from pre-mining vertical degas holes, capturing methane by horizontal drilling within active underground mines, or possibly capturing methane from post-mining areas of underground mines, where for a brief period of time gas is still making its way to the surface through existing boreholes. PA DEP annual coal production numbers and MSHA gas liberation numbers will be reassessed annually, as well as new technological developments, with changes made to trend forecasts on future coal production and revisions to estimates of methane gas released per ton of coal mined.