# 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.

According to data reported to EPA from 2011-2013 approximately 90-93% 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 50% of the 60 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 mines have begun to capture and utilize methane gas within longwall underground mines, resulting in a reduction of methane Greenhouse Gas emissions.

**Longwall Mines:**
Production and emission data for active longwall mines in Pennsylvania during 2011-2014 were analyzed to determine an average emission factor of Methane due to longwall mining. See Table 1.

| Table 1 | Production (Million tons of coal)* | | | | Emissions (MMtCO2e)** | | | |
|---|---|---|---|---|---|---|---|---|
| **Mine** | **2011** | **2012** | **2013** | **2014** | **2011** | **2012** | **2013** | **2014** |
| CONSOL Bailey Mine | 10.8 | 10.1 | 11.3 | 12.3 | 2.089 | 1.834 | 2.991 | 2.164 |
| CONSOL Enlow Fork Mine | 10.2 | 9.5 | 10.1 | 10.6 | 2.084 | 1.748 | 1.764 | 1.855 |
| Harvey Mine*** | NA | NA | NA | 3.2 | NA | NA | NA | 0.778 |
| Alpha Cumberland | 6.2 | 6.4 | 5.6 | 7.4 | 1.858 | 2.156 | 2.119 | 2.047 |
| Alpha Emerald #1 | 3.7 | 4.4 | 3.6 | 4.0 | 0.965 | 0.931 | 1.110 | 0.840 |
| **TOTAL** | **30.9** | **30.4** | **30.6** | **37.5** | **6.996** | **6.669** | **7.984** | **7.684** |

*Production data taken from http://www.portal.state.pa.us/portal/server.pt/community/bituminous_coal_mining_activities/20871

**Emission data taken from http://www.epa.gov/ghgreporting/

***Harvey Mine began operation in 2014

Based on the data provided in Table 1, an emission factor of .228 MMTCO2e / ton of coal was used in calculating projected emissions for longwall mines through 2030. The emission factor is equivalent to 475 $ft^3$ $CH_4$ / ton of coal.

**Non-Longwall Underground Mines:**

Production and emission data for other active underground bituminous mines in Pennsylvania during 2011-2013, where data were available, were analyzed to determine an average emission factor of methane due to underground mining. See Table 2.

| Table 2 | Production (million tons Coal)* | | | Emissions (MTCO2e)** | | |
|---|---|---|---|---|---|---|
| **Mine** | **2011** | **2012** | **2013** | **2011** | **2012** | **2013** |
| 4 West Mine | 1.2251 | 1.4959 | 1.6113 | 62,458 | 61,193 | NA |
| Cherry Tree Mine | 0.8840 | 0.6165 | 0.5872 | 52,547 | 31,169 | 19,355 |
| Clementine Mine | 0.2346 | 0.4040 | 0.4439 | 45,494 | 39,054 | 14,437 |
| Gillhouser Run Deep Mine | 1.2300 | 0.2101 | 0.2557 | NA | NA | 23,280 |
| Logansport Mine | 0.8776 | 0.7229 | 0.3299 | 96,610 | 89,073 | 79,185 |
| Lowry Mine | 0.3522 | 0.3211 | 0.2395 | 47,807 | 43,693 | 54,573 |
| Parkwood Mine | 0.0000 | 0.0538 | 0.2535 | NA | NA | 18,100 |
| Starford Mine | 0.0934 | 0.0726 | 0.0345 | 13,980 | 68,417 | 53,678 |
| Toms Run Mine | 0.2847 | 0.3298 | 0.4572 | 53,246 | 59,584 | 88,744 |
| Tracy Lynne Mine | 0.2916 | 0.2793 | 0.3594 | 81,878 | 58,958 | 52,014 |
| **TOTAL** | **5.4732** | **4.5062** | **4.5720** | **454,020** | **451,141** | **403,366** |

NA: Not Available

* Production data taken from http://www.portal.state.pa.us/portal/server.pt/community/bituminous_coal_mining_activities/20871

** Emission data taken from http://www.epa.gov/ghgreporting/

Based on the data provided in Table 2, an emission factor of 0.09 MMTCO2e / ton of coal was used in calculating projected missions for underground bituminous non-longwall mines through 2030. The emission factor is equivalent to 189 $ft^3$ of $CH_4$ / ton of coal.

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.

**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 25. One million cubic feet of methane is equal to 479 metric tons of $CO_2$ 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 ($ft^3$ $CH_4$ per ton coal mined)
- Methane capture target from longwall mines
- Coal mining emissions for underground bituminous non-longwall mining ($ft^3$ $CH_4$ per ton coal mined)
- Methane capture target from underground bituminous non-longwall mines.

National data inputs were used for the following parameters:

- Natural gas value assumed to start at $2.50 /MMBtu and increase by 3% a year.
- Methane emission factors for all surface mining and Anthracite mining from U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.
- 2030 coal production is based on EIA Annual Energy Outlook 2015 (table A-15) forecast for Appalachia production declining by 11%. Note: This 11% does not take into consideration additional coal reductions that may occur if the Clean Power Plan is implemented.

**Table 3. Summary of Estimated Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2013 Levels, no additional Methane capture**

| | Methane Emission Factor (ft3/t) | Coal (tons) | Methane (Million Cubic Feet) | MMTCO2e |
|---|---|---|---|---|
| Anthracite Underground Mines | 138.3* | 87,889 | 12.2 | 0.006 |
| Anthracite Surface Mines | 138.3* | 4,590,820 | 635 | 0.304 |
| Bituminous Surface Mines | 138.3* | 8,526,774 | 1,179 | 0.565 |
| Room & Pillar Bituminous Underground Mines | 189 | 16,018,737 | 3,028 | 1.450 |
| Longwall Bituminous Underground Mines | 475 | 30,594,284 | 14,523 | 6.961 |

| | | | | |
|---|---|---|---|---|
| **Totals for Coal Mining in Pennsylvania** | | **59,818,504** | **19,377** | **9.28** |

*Methane emission factors are from U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.

As illustrated in Table 3 above, in Year 2013 reported GHG emissions from all coal mining activity in Pennsylvania were 9.3 million metric tons $CO_2$ equivalent (MMtCO2e). Future emissions are expected to drop commensurate with projected decreases in coal mining activity. Table 4 below shows 2030 GHG emissions estimated at 8.3 MMtCO2e a 14% reduction in GHG from the 2013 baseline. In Table 4, the 2030 GHG emissions assumes no methane capture is in place. In contrast, if the goal of 10% capture of this work plan is achieved in gassy, underground mines and there is a decrease in Pennsylvania coal production the resultant emissions, as shown in Table 5 below, are estimated to be 7.51 MMtCO2e, a decrease of approximately 19% from the Year 2013 baseline.

**Table 4. Summary of Estimated and Projected Coal Mine Methane Emissions from Pennsylvania Coal Mines*- 2030 Levels with No Capture in Gassy Underground Mines**

| Mine Type | Methane Emission Factor ($ft^3$ / ton) | Coal (tons)** | Methane (Million $ft^3$) | MMTCO2e |
|---|---|---|---|---|
| Anthracite Underground Mines | 138.3* | 78,221 | 10.8 | 0.005 |
| Anthracite Surface Mines | 138.3* | 4,085,830 | 565 | 0.271 |
| Bituminous Surface Mines | 138.3* | 7,588,829 | 1050 | 0.503 |
| Room & Pillar Bituminous Underground Mines | 188 | 14,256,676 | 2685 | 1.286 |
| Longwall Bituminous Underground Mines | 475 | 27,228,913 | 12925 | 6.191 |
| **Totals for Coal Mining in Pennsylvania** | | **53,238,469** | **17,236** | **8.26** |

*Methane emission factors are from U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.
**Assumed an 11% reduction in PA coal (tons mined) based on EIA Annual Energy Outlook 2015 (table A-15).

**Table 5. Summary of Estimated and Projected Coal Mine Methane Emissions from Pennsylvania Coal Mines* - 2030 Levels with 10% Methane Capture in Gassy Underground Mines**

| Mine Type | Methane Emission Factor ($ft^3$ / ton) | Coal (tons) | Methane (Million $ft^3$) | MMTCO2e |
|---|---|---|---|---|
| Anthracite Underground Mines | 138.3* | 78,221 | 10.8 | 0.005 |
| Anthracite Surface Mines | 138.3* | 4,085,830 | 565 | 0.271 |
| Bituminous Surface Mines | 138.3* | 7,588,829 | 1050 | 0.503 |
| Room & Pillar Bituminous Underground Mines | 188 | 14,256,676** | 2417 | 1.158 |
| Longwall Bituminous Underground Mines | 475 | 27,228,913** | 11633 | 5.572 |
| **Totals for Coal Mining in Pennsylvania** | | **41,485,589** | **14,050** | **7.51** |

*Methane emission factors taken from U.S. EPA 2009 published emission factors for post-mining processing of coal on the surface.
**Assumed 10% reduction in methane emissions.

**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 but at current natural gas prices and challenges associated with securing rights-of-way for the gathering systems from surface landowners, the 10% goal will be difficult to achieve without some financial incentives such as a production tax credit or investment tax credit. The 10% target is technically achievable with a combination of pre-mining gas exploration into the coal formation to be mined, capturing methane from pre-mining vertical/horizontal degas holes, capturing methane by horizontal drilling within active underground mines, and/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.

**Economic Cost**:
At present, there is no net financial benefit to coal mine owners/operators given current and forecasted natural gas prices versus the cost to drill a well and install the necessary gathering systems to collect the gas from the wells. Projections for future methane value were based on an estimated current value of $2.50 per MMBtu and assume a 3% annual increase. These prices ranged from $2.50 to $3.89 per MMBtu between 2015 and 2030. Capital costs are assumed to be about $1.4 million per well which includes the well, gathering, and processing. Each panel would need 2 wells and a panel gets mined in a year. In most cases, the wells are no longer of use after the longwall mines through the seam so the useful life of a well is between 1-3 years, depending on how far in advance of the longwall the wells are drilled.

Two of the mines have two panels operating per mine simultaneously, so a total of 14 wells will be needed each year for a total annual cost of $19.6 million. The calculated net present value of this initiative reflects a net cost of approximately $157 million. The cost effectiveness is $12.42 per ton of CO2e reduced.

| **Table 6** | **2015** | **2020** | **2030** |
|---|---|---|---|
| Room & Pillar Bituminous Underground Mines (ton coal) | 15,902,491 | 15,333,790 | 14,256,676 |
| Longwall Bituminous Underground Mines (ton coal) | 30,372,264 | 29,286,100 | 27,228,912 |
| Methane Emission Room and Pillar (million ft3) | 2,995 | 2,888 | 2,685 |
| Methane Emission Longwall (million ft3) | 14,417 | 13,902 | 12,925 |
| Room and Pillar Methane Capture (million ft3) | 300 | 289 | 269 |
| Longwall Methane Capture (million ft3) | 1,442 | 1,390 | 1,293 |
| Total Methane Capture (million ft3) | 1,741 | 1,679 | 1,561 |
| Projected value of Methane per million btu (assumes a 3% increase per year) | $2.50 | $2.90 | $3.89 |
| Projected value of ft3 Methane (assumes a 3% increase per year) | $0.00253 | $0.00293 | $0.00394 |
| Projected total value of captured Methane ($ million) | $4.41 | $4.92 | $6.15 |
| Estimated cost of Capture equipment ($ million) | $19.60 | $19.60 | $19.60 |
| Net cost (savings) of methane capture | $15.19 | $14.68 | $13.45 |
| **Emission reduction annual (MMTCO2e)** | **0.834** | **0.804** | **0.748** |
| **Cost Effectiveness ($ / ton)** | **$18.22** | **$18.25** | **$17.98** |

| | **2030 Annual** | | | **2030 Cumulative** | | |
|---|---|---|---|---|---|---|
| | **Reductions (MMtCO2e)** | **Cost ($MM)** | **Cost-Effectiveness ($/tCO2e)** | **Reductions (MmtCO2e)** | **Total NPV ($MM)** | **Cost-Effectiveness ($/tCO2e)** |
| Coal Mine Methane | .748 | $13.45 | $17.98 | 12.643 | $156.98 | $12.42 |