Global Methane Initiative Coal Subcommittee
Policy White Paper
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Flaring of Coal Mine Methane: Assessing Appropriate Opportunities

Executive Summary

This white paper summarizes the approach of the Global Methane Initiative Coal Subcommittee towards coal mine methane (CMM) projects that involve mitigation-only of drained gas through flaring. Flaring projects would be preferred to venting methane gas to the atmosphere, and may be appropriate in a number of cases where it is infeasible or impractical to recover the drained gas for energy use. Flaring-only projects should be the option of last resort for drained gas CMM projects.

I. Global Methane Initiative: New Emphasis on Methane Abatement

Methane (CH_4) is a hydrocarbon and the primary component of natural gas. Methane is also a potent and abundant greenhouse gas (GHG), which makes it a significant contributor to climate change, especially in the near term. Methane is the second most abundant GHG after carbon dioxide (CO_2), accounting for 14 percent of global GHG emissions in 2005. Though methane is emitted into the atmosphere in smaller quantities than CO_2, its global warming potential (GWP, the ability of the gas to trap heat in the atmosphere) is 21 times greater.[1] As a result, methane emissions currently contribute to more than one-third of today's anthropogenic warming.

Globally, methane from coal mining activities accounts for 6 percent of total methane emissions resulting from human activities. In 2010, estimated worldwide coal mine methane (CMM) emissions totaled nearly 408 million metric tons of carbon dioxide equivalent ($MMTCO_2E$), or about 28.6 billion cubic meters (BCM). By 2020, the world's coal mines are expected to produce annual emissions of 449 $MMTCO_2E$ (31.4 BCM).[2]

Historically, CMM has been, and continues to be, considered primarily a safety hazard and an impediment to coal production. As a result, CMM was typically vented to the atmosphere through ventilation and drainage systems. However, in recent decades, awareness of methane's environmental impact as a GHG, in conjunction with higher energy prices, has encouraged the development of a number of technologies for beneficially using CMM, including for town gas, for electric power production, and for industrial boiler fuel. Furthermore, the potential efficacy of technologies for oxidizing the very low methane concentrations (typically below one percent) contained in ventilation air exhausts from gassy underground coal mines has been demonstrated, and other ventilation air methane (VAM) mitigation technologies are in the research and development pipeline.

In September 2010, the Global Methane Initiative (GMI) was formally launched as a successor to the successful Methane to Markets Partnership that was originally chartered in 2004.[3] GMI is a public-private international partnership that now includes 41 Partner countries. GMI aims to reduce methane emissions from key sectors including landfills, coal mines, oil and natural gas

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[1] On a 100-year time frame. Based on IPCC Fourth Assessment Report (AR4), IPCC 2007 – (http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_synthesis_report.htm)

[2] Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gases 1990-2020 (EPA Report 430-R-06-003) – (http://www.epa.gov/climatechange/economics/downloads/GlobalAnthroEmissionsReport.pdf)

[3] See the Global Methane Initiative website: www.globalmethane.org

production, agriculture, and wastewater. Historically, the Partnership focused primarily on methane capture and use, rather than emphasizing abatement-only projects that destroy methane without any energy recovery benefit. The newly-anointed GMI Steering Committee formally adopted revised Terms of Reference (TOR) language to expand the Initiative's scope to explicitly include methane abatement in addition to recovery and use. The Steering Committee charged each Subcommittee to evaluate the role of methane abatement within their sector and to update the sector Action Plan accordingly.

Since its inception the Coal Subcommittee has focused on and encouraged two main types of projects: first, projects that recover and use coal mine methane (CMM), such as for pipeline injection, industrial use, or electricity generation; and second, projects focused on mitigation of ventilation air methane (VAM), the very dilute gas emitted from coal mine shafts in large quantities. Because of its dilute nature, it is difficult to recover the energy in the VAM, even though VAM collectively is the largest single source of methane emissions from coal mines. As a result, the majority of VAM projects are abatement-only; they oxidize the methane in the ventilation exhaust stream without recovering any energy. Thus VAM projects are typically (but not always) of the "abatement only" type.

Besides VAM, the other principal type of abatement-only project applicable to the CMM sector is flaring of drained CMM, including abandoned mine methane (AMM). Flaring oxidizes or destroys CMM collected from boreholes in advance of or during mining (e.g., from gob holes or in-mine drainage) through open or enclosed combustion (i.e., flare). The primary purpose of flaring CMM is oxidation of methane, converting it to carbon dioxide, a far less potent greenhouse gas. To offset project costs, carbon emission reduction credits may be available in certain cases for flaring projects.

The principal concern associated with flaring CMM at or near a coal mine has been the safety – whether actual or perceived – of doing so. Flaring itself has been a long-standing global practice in industries handling combustible materials such as oil and gas production, petroleum refining, municipal solid waste landfills, and chemical manufacturing. At the very least, safe flaring requires rigorous design incorporating flame and detonation arrestors, seals, sensors, and others safety devices. Conceptually, the safety risk of flaring is no different from that of a CMM boiler, a well-established CMM application[4].

However, the coal mining industry and regulators in certain countries, such as the United States, have been traditionally reluctant to encourage flaring projects at coal mines. In contrast, CMM flares have operated successfully in a number of countries. The GMI International Coal Mine Methane Project Database identifies 23 CMM projects that are using flares, either in conjunction with energy recovery technologies, or as a stand-alone mitigation technology, including: Australia (5), South Africa (1), Ukraine (5), United Kingdom (10), and Mexico (2). Section VII includes a summary of selected flaring projects around the world.

In the past, the Coal Subcommittee has only briefly addressed the issue of flaring in the CMM sector. At the May 2006 Subcommittee meeting, Project Network members offered a memorandum[5] proposing a policy that flaring CMM should only be considered as a secondary

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[4] United Nations Economic Commission For Europe and Methane to Markets Partnership, *Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines*, ISBN 978-92-1-117018-4, ISSN 1014-7225, 2010 http://www.unece.org/energy/se/pdfs/cmm/pub/BestPractGuide_MethDrain_es31.pdf

[5] Schultz, Karl and Schultz, Lee. *Flaring Coal Mine Methane: When Does It Contribute to Sustainable Development?* May 2006 http://www.globalmethane.org/documents/coal_flaring_white_paper.pdf

option if CMM utilization is not technically or economically viable. Subsequently, the Subcommittee has not discussed an official position on flaring-only projects.

Based on the directive from the GMI Steering Committee to specifically address abatement-only opportunities in each sector, the Coal Subcommittee agreed (at its 2010 meeting in Beijing, China) to develop a draft position paper on flaring (using information from the 2006 memorandum as appropriate). This paper briefly summarizes the key issues involved with flaring-only CMM projects and proposes a framework for guiding decisions about when flaring may be viewed as an acceptable CMM abatement option from a best practice perspective. This paper specifically focuses on flaring of drained CMM and does not address the VAM abatement-only projects.

II. Project Considerations and Economic Feasibility: Comparison of CMM Use and Flaring

In many cases, CMM drainage gas can be used in a wide range of projects that recover the energy of the CMM for productive uses such as electricity generation, process heat, or pipeline natural gas. The recovery of CMM's energy value generally offsets the need for an equal quantity of fossil fuel and its associated GHG emissions. However, on many occasions there are economic or technical barriers to installing CMM end-use projects, and in these cases flaring (abatement-only) projects should be considered for mitigation of part or all of the gas, especially where there is "stranded" gas, remote from either electric or natural gas transmission lines.

Economic and Technical Considerations

Available data suggests that there are several hundred CMM end use projects around the globe, but there are a limited number of projects that flare CMM for a portion or all of the drained gas. Out of 309 projects listed in the GMI International Coal Mine Methane Project Database, only 10 projects are flaring-only projects and 13 of the energy recovery projects include flares for destruction of gas that cannot be used in the energy recovery equipment.

In some cases, a flaring-only project may prove to be a more economical and technically feasible option compared to an energy recovery project, based on a combination of one or more of the following factors:

- Proximity to an electrical connection
- Price of electricity or fuel being replaced
- Existence of a local heat demand
- Price of heat
- Proximity of a natural gas pipeline
- Gas quality
- Gas flow variability
- Local administrative regulation (e.g., environmental, ownership, safety)

Flares also offer the potential advantage of shorter planning, design and installation schedules, in conjunction with much lower capital and operating costs than many energy recovery project types. Flares can represent a significantly less capital-intensive option when compared to energy recovery projects, primarily due their lower capital and operating costs. For example, US EPA's Coal Mine Methane Project Cash Flow Model[6] estimates the capital cost of a typical CMM drainage flaring project to be 5 to 10 percent of the cost of a CMM electricity generation project. The operating and maintenance costs of a CMM flaring project may be similarly proportionate to those of an energy recovery project. Of course, energy recovery projects have income directly associated with the recovered energy, thereby offsetting the higher costs. In contrast, flaring projects may only have an income stream associated with carbon reduction credits.

Flaring can also serve as an important initial CMM recovery stage leading up to an energy project (i.e., flaring CMM prior to an energy project becoming operational). Flares are often an integral component of an energy project, used for the destruction of CMM during periods of unacceptable CMM quality, excessive CMM flows or maintenance of the energy recovery equipment. As such, flaring can serve as an interim measure, destroying CMM and earning carbon credits, while a more full-fledged energy project is being implemented.

Greenhouse Gas Emission Reductions

In terms of greenhouse gas emissions, flaring CMM significantly reduces methane emissions that would have been otherwise vented to the atmosphere. Flaring alone wastes a valuable energy resource by emitting CO_2 without recovering any beneficial energy. An energy recovery project generates power for the same CO_2 emissions and reduces the need to consume a similar amount of fuel at an power plant. The following is a greenhouse gas emission reductions comparison of CMM flaring and energy recovery:

- Flaring CMM drainage has the GHG benefit of destroying 1 kg of methane with a GWP of 21 kg CO_2e, to 2.75 kg of CO_2, thereby providing a net equivalent benefit of avoiding the release of 18.25 kg CO_2e.
- A similar sized energy recovery project that off-sets an equivalent amount of fossil fuel combustion would result in a benefit of 18.25 kg CO_2e, just like the flare project, but would have an additional benefit of offsetting 2.75 kg CO_2 that would have been emitted from a power plant, for a net benefit of 21 kg CO_2e.

Thus, energy recovery projects conserve energy and result in approximately 15 percent fewer GHG emissions.

III. When to Flare?

Because flaring-only does not provide the same level of energy and environmental benefits of energy capture for drained CMM, flaring-only projects should not be the first option considered when planning methane emission mitigation or abatement. Project stakeholders should conduct a preliminary project scoping analysis to evaluate the costs and benefits of all technologically viable mitigation options.

There is a hierarchy of optimal end use options for CMM based on site-specific economic and market demands (Table 1). Projects using and recovering energy from the highest quality (highest methane concentration) drained CMM would be at one end of the spectrum, and mitigation-only projects (i.e., flaring) would be at the other. Drainage gas with high methane

[6] http://www.epa.gov/cmop/resources/cashflow_model.html

concentrations, such as over 85 percent, present the most project options since the fuel can replace natural gas with minimal effort. Drainage gas with methane concentrations between 40 to 85 percent can be used in direct combustion applications such as engine-generator set, dryers, and boilers with little treatment or combustor modifications. Low methane concentrations, such as below 40 percent, have more limited utility (without significant treatment to increase the heating value).

Table 1: Suitable Uses for CMM Based on Methane Concentration of Drainage Gas

Methane Concentration of Drainage Gas	Natural Gas Pipeline	On-site Combustion Applications	Flaring
High methane concentrations **(over 85 percent)**	✓✓	✓✓	✓✓
Medium methane concentrations **(40 to 85 percent)**	✓	✓✓	✓✓
Low methane concentrations **(below 40 percent)**	–	✓	✓✓
Potential Revenues where infrastructure and demand is available	High	Intermediate	Lower

✓✓ Highly suitable use in proven commercial-scale projects; CMM requires little or no treatment
✓ Suitable use in proven commercial-scale projects; CMM will likely require some treatment

The feasibility of any energy recovery project is significantly impacted by a number of factors such as local energy prices, onsite energy demands and accessibility to energy markets. To assure that sustainability is adequately factored into the project planning, selection, and approval process, projects should consider the technical and economic viability of a wide range of technologies that exploit methane's energy content in some manner.

This process is not intended to be an "all or nothing" approach. In some cases, a mine site will not be able to utilize all of the available CMM in an energy recovery project and could consider a combined energy recovery and flaring project to mitigate all of the captured methane. When project stakeholders are contemplating such a mixed recovery and flaring option, a stepwise process can be used to first determine what portion of methane emissions meets the investment thresholds for energy recovery. Ideally, only the CMM exceeding reasonable investment thresholds due to fluctuations in methane quantities or qualities would be considered for flaring. Combined use and mitigation projects are highly desirous as they would mitigate all (or nearly all) methane emissions rather than venting the methane that cannot be economically recovered for energy use.

As an illustrative example, the following is one possible stepwise decision process for evaluating project options:

- ☑ Conduct a preliminary project scoping analysis to identify project-site features and any major impediments to developing CMM energy recovery projects.
- ☑ Identify all technically feasible CMM use options.
- ☑ Eliminate any options for which site-specific markets do not exist or could not be created.
- ☑ Assess capital investment, cash flow, and expected revenues, including sale of carbon credits and any other available economic incentives.

☑ Evaluate key economic parameters such as internal rate of return (IRR), return on investment (ROI), capital investment per unit output ($/MW), cash flow profile, etc.

☑ Select CMM energy recovery projects for which the project would be technically viable and could be justified based on project economics.

☑ Select CMM flaring-only projects for cases in which CMM energy recovery projects would not be technically feasible or could not pass economic hurdles.

IV. Conclusions

The GMI Coal Subcommittee understands and appreciates the potential benefits that coal mine methane flaring as methane abatement can provide when applied in an appropriate setting, including as part of an overall integrated CMM project. From an environmental perspective, it is better to flare excess or stranded CMM rather than to vent it to atmosphere, as it reduces the overall greenhouse gas emissions. In conclusion, the following considerations should guide CMM flaring methane abatement projects:

- Flaring of CMM is deemed to be a generally accepted, proven, safe technology that does not pose an intrinsic risk. Safety concerns must be evaluated and addressed in every case, and all applicable regulations strictly followed.

- Flaring-only of drained CMM is most appropriate where the gas is low-quality (e.g., lower than 40% methane) and energy recovery is infeasible because the gas is not needed onsite or is not accessible to energy markets.

- Flaring of CMM should be the option of last resort for drained CMM, as CMM energy recovery end-uses are more desirable where technically and economically feasible. Flaring of high-quality CMM (above 85%) is not encouraged.

- Flaring is ideal as a component of an integrated overall end-use project to mitigate excess methane that would not otherwise be used.

V. Selected Examples of Mine Methane Flaring Projects

Below are selected examples of operational mine methane flaring projects, including one trona mine project.

Project	Project Year	Gas Flow to Flare	Project Summary
Riccall Mine, United Kingdom	unknown	1 x 2,000 m^3/hour enclosed flare	Riccall Mine's life had only 12 months remaining, and therefore it was determined that the site was ideal for demonstrating flaring technology, especially as the short remaining mine life meant that the capital investment for power generation was impossible for a 12 month payback. Riccall already used CMM for its onsite heating within a fire tube hot water

			boiler, and flaring was used for any gas in excess of that used in the boiler.
Rossington Colliery, United Kingdom	2004	1 x 2,000 m^3/hour enclosed flare	Rossington had only a 12 month mine life, and therefore it was determined that the short mine life meant that the CAPEX investment for power generation was impossible for a 12 month payback. The on-site boiler used diesel fuel, however it was considered that over the short mine life, investment in a new CMM boiler burner and fuel gas delivery pipeline was not viable.
Welbeck Colliery, United Kingdom	2002	2 x 2,000 m^3/hour enclosed flare (in parallel with 2 x 1.4 MWe generators and gas boiler)	Welbeck Colliery is an active deep mine with extensive closed workings. The methane extraction plant draws enough gas from the mine on a steady basis to support their boiler and two engine generators for 75% of the year. The 75% availability for these engines allows the equipment to exceed the mine group's IRR threshold. Had another generator been installed it would have only achieved 50% availability, and the IRR threshold would not have been achieved. As a result of the extensive and deep closed mine workings, when barometric pressure drops, the quantity of the gas being drained far exceeds the amount which would be necessary to run a third generator. The two enclosed flares were installed to use the gas which could not be used in the generation plant or boiler on a continuous basis, and also to destroy any excess gas desorbed from the mine during a barometric drop. When generators are not available due to maintenance or breakdown, flares are used to ensure methane destruction continues.
Thoresby Colliery, United Kingdom	2001	1 x 2,000 m^3/hour enclosed flare (in parallel with 2 x 1.4 MWe generators)	Similar general commercial and sustainability justification as Welbeck Colliery. Although the boiler at Thoresby is coal fired, the marginal cost of coal as a fuel resulted in a longer payback period for boiler modification or waste heat recovery (and therefore failed to reach the internal IRR threshold).
Chertinskaya Kokovskaya Mine, Kuzbass, Russia	Unknown	1 x 1,500 m^3/hour enclosed flare	Chertinskaya uses gob wells for post drainage. The gob wells are isolated and the local electrical connection is insufficient to support power generation. Relatively short well life and variable concentration, combined with extremely low natural gas prices and lack of local pipeline negate a pipeline injection. These factors, in combination with no heat demand, drive the project toward flaring. The project was commissioned, but credits were not generated as Joint Implementation in Russia has only just started.
Solvay	2010	1 x 2,549 m^3/hour	In 2010, Solvay started using gob wells in a

Chemicals Inc., Trona Mine, Green River, Wyoming	enclosed flare	remote location. They have only a short history of using this type of drainage and the number of wells is small. This means that a continuous gas flow cannot yet be supplied. A flare is used as there is no local electrical connection and the gas supply is not sufficient (and not enough gas flow history existed to justify a substantial investment) to meet the IRR investment threshold for power generation. It is the intention in the future, when more gas is available and greater certainty of gas flow history exists, to couple the gob wells together and use the CMM for process heat. The flare will then be used when the gas flow supply exceeds that which can be used at the mine, or when there is no mine process demand for heat.