Methane Capture and Utilization

Regulations, Policies, and Benefits

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Coalification, the biological and geological processes by which biomass is converted into coal, produces methane as a byproduct. Methane remains in coal seams and rock strata until released by pressure changes from erosion, faulting, or mining. Deep mines have a higher capacity to store methane and therefore, release more methane per ton of coal mined than surface mines. (U.S. EPA 430-K-04-003).

Methane gas is the most dangerous gas released during underground mining operations. It is an explosive, flammable gas and at high enough concentrations, it replaces the oxygen in the air and can suffocate. Methane can cause deadly mine explosions when ignited by a flame or spark.

Methane vented to the atmosphere is an environmental hazard. It is a potent global warming gas and contributes to increased global temperature trends.

Draining, capturing, and utilizing methane are strategies that can create safer working conditions in a mine, reduce the amounts of greenhouse gases emitted into the atmosphere, provide an otherwise lost energy resource, and ease underground ventilation mechanisms thereby increasing coal production.

Although methane capture and utilization occurs worldwide, many issues complicate the extent to which it is implemented.

Implementing Coal Mine Methane Capture and Utilization—Concerns and Strategies

Investigating international best practices for methane capture and utilization in an effort to analyze strategies for adoption in the United States may not produce straight-forward results. Significant differences in socio-economic, political, and cultural environments blur outlooks for any one policy. A better approach may be to analyze various strategies in countries that successfully capture and utilization methane.

Analysis of successful programs around the world has shown that development of coal mine methane (CMM) recovery increases by the existence of major stakeholders, institutional development, increased use of new technology, utilization of existing economic incentives, defined gas property rights, unsubsidized free gas markets, and education and information dissemination of coal mine methane resources (U.S. EPA, January 2009).

A. Regulatory Issues

Regulatory provisions are often obstacles to the development of methane gas utilization. Ill-defined property rights, lack of clarity of the regulations for ownership of coalbed methane (CBM) and CMM, and complicated permitting processes in developing countries hinder progress. It is helpful for all entities engaged in CMM development to have uniform regulatory frameworks for ownership.

Several countries have successfully developed CMM capture and utilization projects utilizing very different strategies. Several examples are described below:

Ukraine

In the Ukraine, coal mine methane is under a mineral resource regulatory framework (the Code of Ukraine on Mineral Resources) and is regulated at the national level. Essentially, the people of the Ukraine own the country's mineral wealth. CMM capture and utilization follows the standard mineral licensing procedures. Coal seam degassing during coal production follows safety regulations. If methane extraction is solely for safety protocols, then the methane is not classed as a mineral wealth, but a waste. In these circumstances the waste is owned by the mine owner. These uncertainties concerning classification of methane and the resulting ownership issues negatively impact development and licensing. Disputes occur in many other countries as well if there are legal ambiguities of CBM and CMM ownership. (U.S. EPA, January 2009).

United Kingdom

As in the Ukraine, the U.K. government owns methane associated with coal production and regulates the rights to the CMM gas. The government can pass on ownership of the methane through licensing procedures when the methane is recovered. Mine gas, however, is considered a petroleum product and therefore regulation is not under Coal Authority responsibility. Under the Petroleum Act of 1998, the Department of Business Enterprise and Regulatory Reform awards Petroleum Exploration and Development Licenses (PEDL) to cover CMM issues. The government also issues Methane Drainage Licenses (MDL) to regulate methane drainage for safety reasons. MDLs usually cover smaller mines than do PEDLs and do not involve exclusive rights to CMM. MDLs can overlap PEDLs and cause jurisdictional issues between companies. (U.S. EPA, January 2009).

United States

Again, there is controversy over methane ownership. Carbon-based mineral rights and methane gas are under different jurisdictions in the U. S. The coal lessee has the right to capture and discharge methane with no gas lease requirement. If the operator utilizes the extracted CMM, then federal leasing procedures must be followed and royalties paid to the government. Some states have tried to clarify methane ownership issues but the federal government has not approved of the regulations. Methane ownership disputes are now settled on a case-by-case basis.

This state vs. federal government controversy occurs in many countries with similar types of governments. Some countries with federal forms of government lack a national framework for legislating CMM. However, other countries have found solutions. In Australia, each state has its own legislation and licensing arrangements for CMM. Similarly, Canadian provinces own and sell rights to CBM. (U.S. EPA, January 2009).

Note: Of the active U.S. mines reporting Ventilation Air Methane (VAM) emissions, drained gas, drained gas utilized and end use, 40 mines either did not drain gas or did not utilize the gas drained. One mine utilized 28% of the drained gas and used it for mine air heating. Six mines utilized 100% of the drained methane for natural gas pipeline injection. Six other mines utilized 5—92% of drained gas for pipeline injection. One mine also used 100% of its drained gas for coal drying and peaking power plant operations (U.S. EPA, Coal Mine Methane Outreach Program).

Germany

Germany has adopted a different approach. The legal framework for CMM capture is held at the federal level. The Federal Mining Authority is responsible for the administration of activities regarding coal mine methane exploration, extraction, and processing. Ownership rights are transferred to the mining company with the license. Licenses are renewed for capture of mine gases for 30 years, but licenses can be withdrawn because of insufficient planning and lack of appropriate extraction technologies.

In Germany, there are no endemic CMM ownership disputes as common in the Ukraine, United Kingdom, or the United States. Germany has developed an effective method of resolving CMM issues and is a world leader in utilizing coal mine methane (U.S. EPA, Coal Mine Methane Outreach Program).

China

China has the most methane capture operations and planned projects, with most at underground coal mines. However, most CMM is low-grade and less than 30% methane (Karacon, et al., 2011). Other hindrances to China's methane capture effectiveness include limited accessibility to gas pipelines, low drainage rates, and vague regulations. (U.S. EPA, Coal Mine Methane Outreach Program).

B. Institutional Frameworks and Economic Incentives

National and local governments play the most important roles in the regulation of rights to methane, project approval, licensing, and permitting.

The development of CMM recovery and utilization projects depends in large part on the demand of methane markets, the availability of CMM, and on project financing. Even if there is funding available for CMM projects, minimum requirements for approval often result in considerable effort being required by the mine owner to make the project successful. This has proved to be a detriment to CMM development.

Some countries offer substantial economic incentives for CMM development. Feed-in tariffs (implemented in France and Germany), grants (offered in Australia), and tax incentives (in the U.K.) promote methane capture and utilization.

Legislation can also promote methane capture. France's Renewable Energy Sources Act of 2000 and Germany's Renewable Energy Act of 2004 create incentives for developing renewable energy sources that includes coal methane. Australia is considering legislation that would decrease the amount of electricity that would be allowed to be generated from coal. Gas Electricity Certificates (GECs) under the Electricity Act of 1994 would require electricity suppliers to source electricity from natural gas, coal seams, landfills, or sewage gas or face governmental penalties. In additional to this measure Australia also provides grants for up to 50% of CMM/CBM project costs (U.S. EPA, January 2009).

CMM utilization has been successful in France, Germany, the United Kingdom, China, India, and the Ukraine. Projects are particularly successful when developed as a package along with greenhouse gas mitigation strategies.

C. Mine Methane Utilization Information Dissemination

Dissemination of CMM utilization information is critical to developing successful capture and recovery programs, especially in developing countries. Some international institutions and governments promote CMM education and practices. Organizations include CMM clearinghouses, methane capture (MC) technology transfer centers, and international cooperative programs.

China founded the first CMM clearinghouse in 1994, the China Coalbed Methane Clearinghouse. In 2002, Russia began their International Coal and Methane Research Center, and India's CMM Clearinghouse started in 2008. Poland founded the Central Mining Institute of Katowice, AGH University of Science and Technology, and the Mineral and Energy Economy research Institute of the Polish Academy of Science.

The Methane to Markets Partnership of the International Energy Agency, the United Nations Economic Commission for Europe, and the U. S. Environmental Protection Agency actively participate in developing CMM recovery projects in China, India, Poland, and Russia.
Two organizations especially active in promoting CMM recovery and utilization are the EPA's Coalbed Methane Outreach Program (CMOP) and the Methane to Markets Partnership. The CMOP is a voluntary government program with the goal to reduce methane emissions from coal mining operations. It promotes profitable recovery and utilization of CMM and works cooperatively with the coal mining industry in the United States and internationally. Their mission goal is to decrease greenhouse gas emissions and address related global warming issues.

Begun in 2004 with 14 member countries, the Methane to Markets Partnership is a voluntary, non-binding framework for international cooperation to advance recovery and use of methane as a clean energy source. Thirty-eight countries now belong to M2M, including the top ten methane-emitting countries (Karacon et al., 2011). The organization strives to bring diverse entities together with government agencies to initiate methane projects.

M2M created the Global Methane Initiative (GMI) in 2010. It builds on the Methane to Market Partnership and encourages more worldwide participation in methane capture and utilization. The United Nations houses two commissions that address CMM issues, the U. N. Economic Commission for Europe and the U. N. Development Programme. There are also bilateral technology transfer centers that have successfully disseminated information about CMM utilization. These include the U.K.-China Coalbed Methane Technology Transfer Project (2001), Methane Extraction and Utilization from Abandoned Coal Mines, the U. K.- India CBM Technology Transfer Project (2003-2005), the U.K.- Russia AMM/CMM34 Technology Transfer Project (2005-2006), and the Development of China's CBM Technology/Canada CO_2 Sequestration Project (2002-2007).

Technologies to Capture and Utilize CMM/CBM

Most degasification systems were designed to lessen the demands on the mine's ventilation system in reducing and controlling methane concentrations. These degasification systems can also be used to capture methane for use as an energy resource. Vertical wells, gob wells, and in-mine boreholes are degasification systems that can be used for methane capture and utilization. The degasification strategy in use will affect the quality and therefore, the uses of the gas collected. For example, only gas that is 95% methane can be used for pipeline injection.

Although high quality methane can also be present in gob wells, mine air can mix with the gob well methane and dilute it over time, resulting in lower quality methane. This lower quality methane can still be used for electricity generation, in on-site preparation plants, for industrial facilities, or in fuel cells.

Methane recovery can occur at three stages in coal mining: 1) before mining begins (pre-drainage CBM extraction), 2) in an operating mine (CMM extraction), and 3) in abandoned or closed mines (AMM/CMM) extraction.

Methane is extracted through drainage systems which can be vertical pre-mine wells, gob wells, or in-mine boreholes. Vertical pre-mine wells are drilled before mining begins. Draining methane increases safety, decreases mining delays, decreases ventilation costs, and reduces methane emissions. Concentrations of methane from pre-drainage of methane from vertical wells are usually greater than 90% and are usually injected into natural gas pipelines or used to generate electricity.

Gob wells are typically used to drain methane from abandoned mines. Mine gas with methane fills fracture zones caused by collapsed strata post-mining. Concentrations of methane from gob well drainage is approximately 20-80% and typically used for heating and power generation. In-mine boreholes are used to capture methane in operating mines. Methane is extracted using existing degasification systems. Mining often de-stresses coal-carrying strata, and methane loses its close adsorption within the coal media. CMM recovery is especially valuable when the concentration of methane is greater than can be easily reduced through standard ventilation practices. Capture methods in these cases attempt to recover the methane before the gas enters mine airways. Often, underground horizontal boreholes are drilled through the coal and accompanying rock. Concentrations of methane are typically greater than 90% for horizontal boreholes and between 30-80% for cross-measure boreholes. Methane from in-mine boreholes is usually a source of heat and power generation.

Though of a very low quality, even mine ventilation air methane (VAM) has been used successful as combustion air in gas-fired engines, turbines, and coal-fired boilers. (U. S. EPA, 430-K-04-003). The first commercial use of technology oxidizing VAM was in New South Wales, Australia.

Of the 54 active U.S. mines reporting VAM emissions, drained gas and drained gas utilized/end use, 40 mines either did not drain gas or did not utilize the gas drained. One mine utilized 28% of the drained gas and used it for mine air heating. Six mines used 100% of the drained methane for natural gas pipeline injection. Six other mines utilized varying amounts of drained gas for pipeline injection, including from 5—92%. One mine also used 100% of its drained gas for coal drying and peaking power plant operations. (U.S. EPA, CMOP)

Note: Methane concentrations vary due to mining techniques in a particular mine, site-specific geological conditions, and CMM capture methods.

Research has shown that key issues to be addressed for successful CMM utilization are

- Mine owners participate fully in CMM recovery and utilization
- Exiting methane drainage systems provide for air intrusion
- Methane gas capture is sustainable
- Infrastructure exists or is built to adequately capture and utilize methane gas

A comparison of gas drainage methods is available at: http://www.unece.org/fileadmin/DAM/energy/se/pdfs/cmm/pub/BestPractGuide_MethDrain_es31.pdf "Best Practice Guidance for Effective Drainage and Use in Coal Mines", ECE Energy Series No. 31, produced by the Economic Commission for Europe and the Methane to Markets Partnership, 2010.

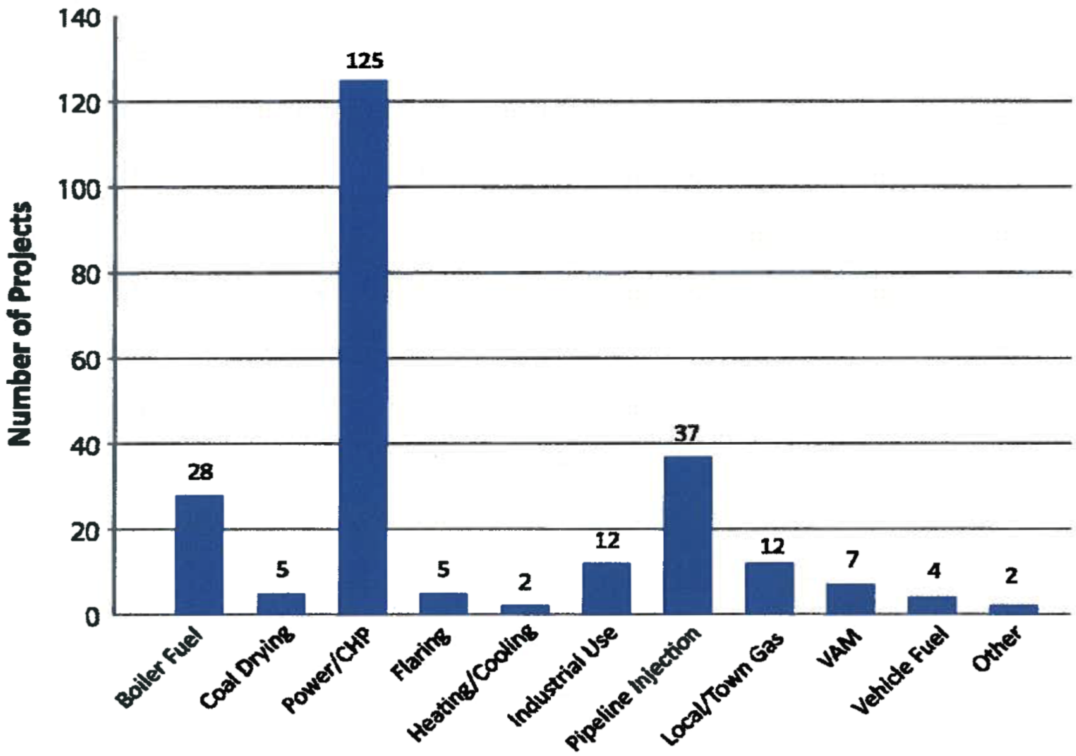
Coal Mine Methane Technologies

Through innovative technologies, recovered coal mine methane can be used for centralized heat and power units (CHP), internal combustion engines, gas turbines, and in boilers that burn CMM or co-fired CMM and coal.

Centralized CHP plants usually generate heat and power through co-generation processes, while decentralized CHP consists of individual units which supply heat and power for local (mine) needs. Surplus energy is then sold to a public grid.

The concentration of CMM determines its potential use and also the method through which electricity is produced. For example, electricity produced by internal combustion engines typically need methane concentrations of approximately 45%, gas turbines use methane with a concentration of approximately 35%, and boilers, used for space heating and water heating, use coal mine methane or a combination of coal mine methane and coal with a methane concentration of 25-30%.

Some methane concentrations may need to be enriched and/or purified to ensure optimal power generation especially when being sold to a public grid. The chart below shows the number of projects for various uses of recovered methane.



(Source: Methane to Markets Partnership, 2009)

Benefits of Development of CMM Recovery and Utilization

The benefits to coal mine and coalbed methane recovery and utilization have been recognized internationally for decades. The Firedamp Drainage Handbook was developed by Verlag Gluckauf for the Commonwealth of European Commodities in 1980. Sponsoring organizations included the U. N. Economic Commission for Europe (UNECE) with 56 countries and Methane to Market with 30 partner countries. It is interesting to note that no Americans were on stakeholder advisory groups or technical peer groups.

The International Energy Agency has recently predicted that developing global economies will increase energy demands by 93% by 2030 largely because of demand from China and India. Meanwhile, coal extraction will be increasingly more difficult because more shallow reserves are mined out causing deeper and gassier mines to be used. These mines can result in more frequent accidents at a time when mine accident fatalities are becoming less acceptable culturally.

Management of CMM also decreases greenhouse gas emissions. Methane has a global warming potential (GWP) twenty times that of carbon dioxide (IPCC, 2007) and totals 14% of global anthropogenic greenhouse gas (GHG) emissions. Coal mines release 6% of global methane emissions (about 400 million tons of $CO_{2\ eq}$ (Mt $CO_{2\ eq}$)/yr). Coal mine methane emissions are expected to increase through 2020 (EPA, 2006, IPCC 2007; M2M, 2008) with estimates as high

as 793 Mt CO_2 eq by 2020 (ESMAP, 2008). Coal mine methane capture and utilization represents a significant opportunity to reduce global greenhouse gas emissions.
Good post-drainage strategies capture 50-80% of gas from a longwall while 50% can be captured from the mine overall. When pre-drainage methods are used in addition to post-drainage strategies, higher captures are achievable (Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines, 2010.)

Complex deep multi-seam and co-located mines greatly complicate the process of predicting gas emissions from interactions among strata, groundwater, and adjacent natural gas reservoirs. Using proven methods for projecting gas flows, adhering to ventilation regulations, and capturing methane gas can reduce the risks of explosions, produce more energy, and mitigate the amounts of methane released into the atmosphere.

Ventilation Systems

The rate of gas extraction depends on both the mine ventilation system and the efficiency of the methane drainage system. The ventilation system's ability to adequately and safely dilute dangerous gases from a gassy coalface will impact the degree to which methane can be safely captured.

Ventilation is one of the most costly expenses of a mine operation. A system that drains and captures methane reduces the costs of ventilating a mine because the methane is drained at a higher purity before it can enter mine airways. At a minimum, methane could be captured only to a point that allows the ventilation system to adequately dilute the remaining methane safely. A ventilation system that merely meets minimum regulatory specifications may not always provide safe conditions in changeable mine atmospheres. More effective methane capture enhances safety, reduces the need for more remediation of mine air, and enhances environmental mitigation.

Ventilation systems and methane recovery and utilization methods are influenced by different coalface layouts. The degree of extraction and type of mining being used, such longwall mining as opposed to room-and-pillar methods, will affect the system of methane recovery that will be most efficient. The ventilation of a gassy face is accomplished by either allowing the pollutants to enter the airways where sufficient ventilation air dilutes the pollutants to safe concentrations or by allowing the discharge, after methane capture, to enter a bleeder shaft for discharge. Most countries regulate the amount of methane that is allowed to enter a bleeder system.

Ventilation must result in a sufficient amount of fresh air for all working areas of the mine, including the methane drainage drilling location. If there is not an adequate amount of fresh air, lower drainage efficiency, unsafe working conditions, and reduced coal productions will result.

Methane Emissions from Abandoned Coal Mines

Most CMM emission estimates consider emissions from active mines only and do not include methane emitted from abandoned coal mines. The U.S. and other countries have thousands of abandoned mines that continue to emit methane which contributes to the greenhouse gas effects from coal mining and represents a lost energy source (Cote et al., 2004). Estimating amounts of methane emitted from abandoned mines requires modeling different from that used in estimating emissions from active mines.

Three types of mine conditions are defined as being abandoned: a non-produced mine with miners working, a non-producing with no miners working but re-opening is a possibility, and a mine with no miner working that has been abandoned for more than 90 days. (Cote et al, 2004). Although many factors influence that rate of CMM emissions from abandoned mines, the total gas content of the coal is most important (EPA, 1990, Grau, et al., 1981). Coal has a large capacity to hold methane compared to other sedimentary rocks. Factors that affect how much will be emitted from an abandoned coal mine are varied. Many abandoned mines eventually flood which stops gas from flowing into a mine from the coal strata. Some abandoned coal mines are sealed to prevent methane emissions; some areas in an active mine are sealed to prevent methane flowing into active areas. It is common for gas to leak out through the seals into the atmosphere or into other parts of the mine.

The EPA has identified abandoned coal mines that are classified as "gassy". These mines represent a potential for methane capture and utilization. Such projects represent the development of a previously untapped energy source, a method to reduce greenhouse gas climate effects, and improved safety conditions.

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