Coal Mine Gas

Utilization Principles

Global Methane Emission

Coal provides 25 percent of global primary energy needs and generates 40 percent of the world's electricity, according to the World Coal Institute.

The anthropogenic release of methane (CH_4) into the environment is a byproduct of the coal mining process and the global warming potential of this methane continues to draw attention globally. Stakeholders responsible for coal and power production are looking for ways to safely and economically mitigate the release of coal mine greenhouse gases.

As shown in Figure 1, methane is a greenhouse gas with an estimated global warming potential of 21. This means that emissions of methane have an estimated effect on global warming equal to 21 times the effect of carbon dioxide. Implementing methods to use CMM instead of emitting it to the atmosphere will help mitigate global warming, improve mine safety, and productivity and generate revenues and cost savings.

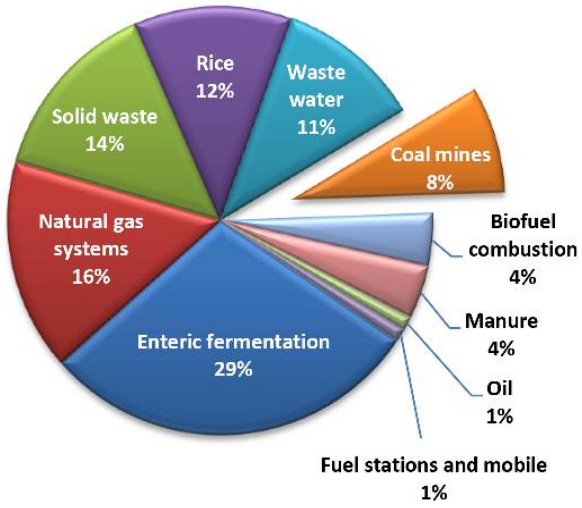
Figure 1. Global Warming Potentials (GWP) and Atmospheric Lifetimes (Years)

Gas	*Atmospheric Lifetime*	*100-year GWP* [a]	*20-year GWP*	*500-year GWP*
Carbon dioxide (CO_2)	50-200	1	1	1
Methane (CH_4)[b]	12±3	21	56	6.5
Nitrous oxide (N_2O)	120	310	280	170
HFC-23	264	11,700	9,100	9,800
HFC-125	32.6	2,800	4,600	920
HFC-134a	14.6	1,300	3,400	420
HFC-143a	48.3	3,800	5,000	1,400
HFC-152a	1.5	140	460	42
HFC-227ea	36-5	2,900	4,300	950
HFC-236fa	209	6,300	5,100	4,700
HFC-4310mee	17.1	1,300	3,000	400
CF_4	50,000	6,500	4,400	10,000
C_2F_6	10,000	9,200	6,200	14,000
C_4F_{10}	2,600	7,000	4,800	10,100
C_6F_{14}	3,200	7,400	5,000	10,700
SF_6	3,200	23,900	16,300	34,900

Source: IPCC (1996)

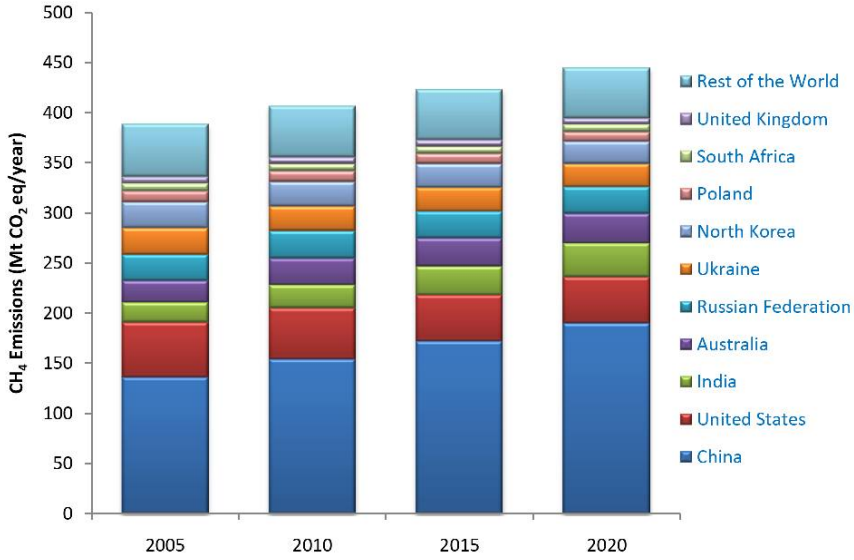
Methane (CH_4) can be released into the atmosphere through sources where it naturally occurs: landfill decomposition, agriculture, gas and oil extraction systems and coal mining activities. Figure 2 displays different sources of methane emission.

Figure 2. Sources of Methane Emissions



When released into the atmosphere through these and other processes, methane remains in the atmosphere for approximately 9 to 15 years. Figure 3 shows past, current and projected amounts of methane released through coal mining activities.

Figure 3. Metric Ton of CO_2 Equivalent ($MtCO_2eq$) from Coal Mining Activities (Source: US EPA 2006)



The Kyoto Protocol, is an international agreement under the United Nations Framework Convention on Climate Change that requires participating countries to reduce their greenhouse gas emissions below levels specified for each of them. These targets must be met within a five-year time frame between 2008 and 2012.

One of the ways Kyoto participants pursue this goal is through the Clean Development Mechanism (CDM). CDM allows developed countries to earn and trade emissions credits through projects implemented either in other developed countries or in developing countries where projects are less expensive, which they can use toward meeting their commitments. CDM projects receive Certified Emission Reduction (CER) credits by demonstrating the difference in environmental impact their cleaner processes produce compared to a conventional method that might otherwise have been used, such as burning coal. The greater the reduction of greenhouse gas emissions, the more credits a project may receive.

Coal Mine Methane (CMM) is one of the most promising and effective greenhouse gases used in CDM projects. CMM is a methane gas formed as a byproduct during coalification that is found within subterranean coal seams. When released during active coal mining, the methane concentration is generally between 25 and 60 percent. Figure 4 below provides a reference point for the composition of CMM compared to other fuel sources. As the table shows, CMM has a higher mix of oxygen and nitrogen than pipeline natural gas and coal bed methane (CBM), which has such a high concentration of methane it can be used in natural gas pipelines with very little treatment.

Figure 4. Typical Fuel (CMM) Composition and Physical Properties

Component	Symbol	Units	Pipeline Natural Gas	CBM	CMM*
Methane	CH_4	vol %	92.3	85.9	**40.0**
Ethane	C_2H_6	vol %	2.5	3.8	---
Hydrogen Sulfide	H_2S	vol %	---	---	---
Oxygen	O_2	vol %	---	2.1	12.6
Nitrogen	N_2	vol %	3.5	8.2	46.8
Others	---	vol %	1.8	0.0	0.6
Lower Heating Value	LHV	MJ/Nm^3	33.2	32.5	**13.4**
Caterpillar Methane Number	MN	---	80	86	100

* Represents one particular site at one particular time

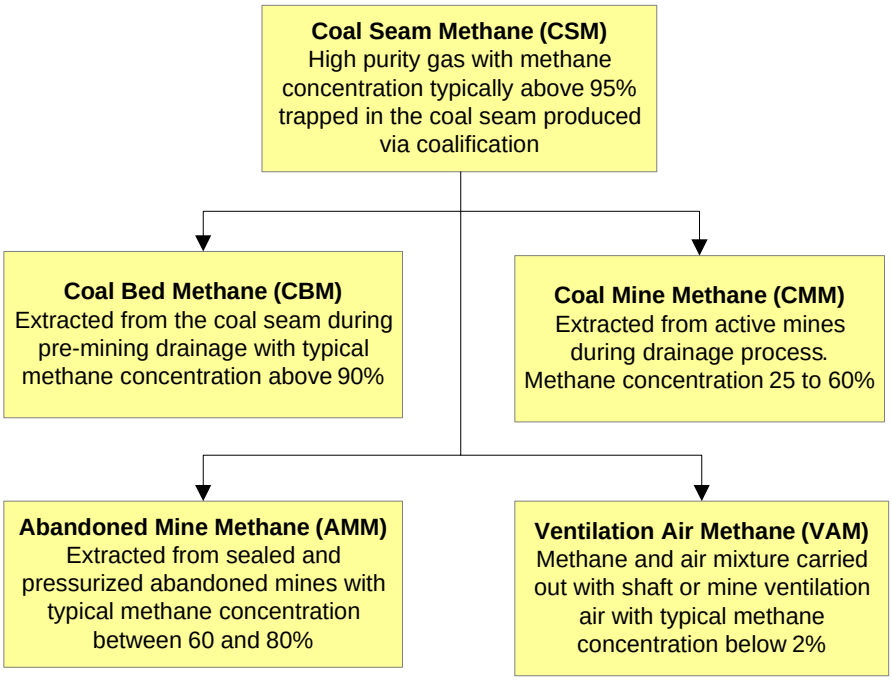
Methane Utilization Projects

There are several options currently available for CMM mitigation, including reciprocating gas engines, gas turbines, industrial boilers and furnaces, and chemical processing. Other technologies like catalytic systems and fuel cells are also being developed.

Sequestering Coal Mine Methane as an alternative fuel for reciprocating gas engine generator sets is a mature and proven technology for greenhouse gas mitigation. Prior to commissioning CMM-fueled power systems, the methane gas composition must be evaluated.

As shown in Figure 5, coal methane utilization projects for can be split into 4 major category depending on the gas extraction method, methane concentration and phase of mining activity.

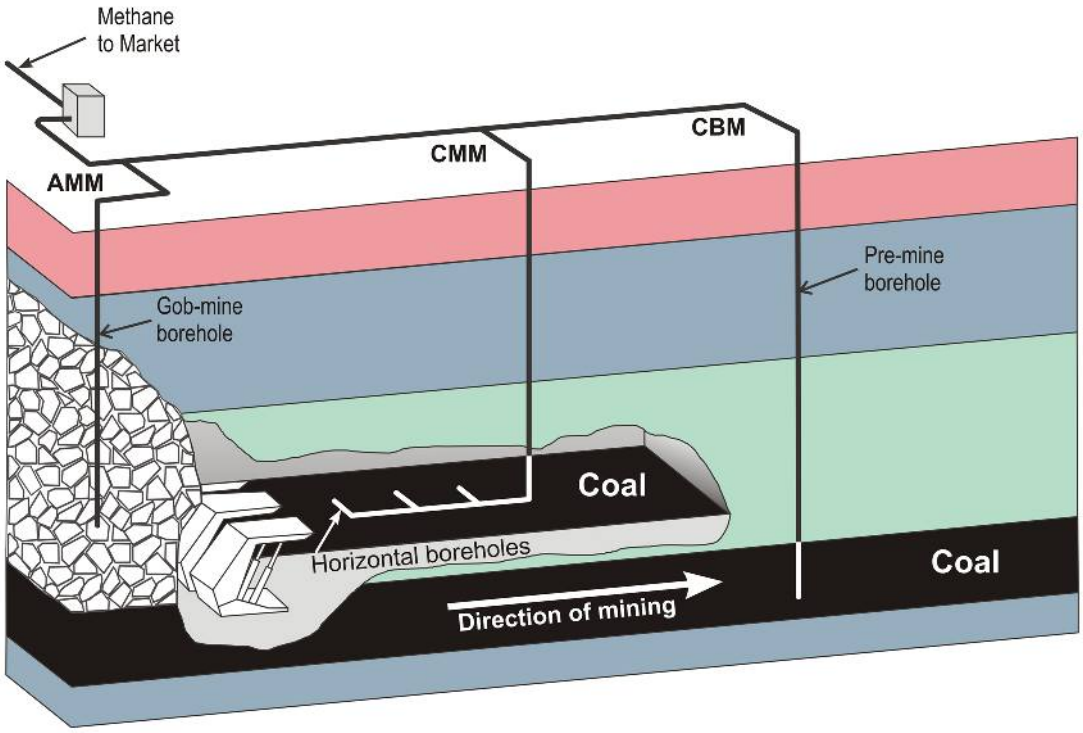
Figure 5. Types of methane utilization projects



VAM extraction is a necessary part of the process of coal mining. Existing mineshaft air must be ventilated to keep the methane content at acceptable levels for miner safety. While the coal seam is actively mined, a large volume of air is pulled through it to remove the methane. The concentration of methane in the recovered air is typically very low, typically in the 0.3 – 1.5 percent range. Because of the low methane concentration in ventilation air, its beneficial use is difficult.

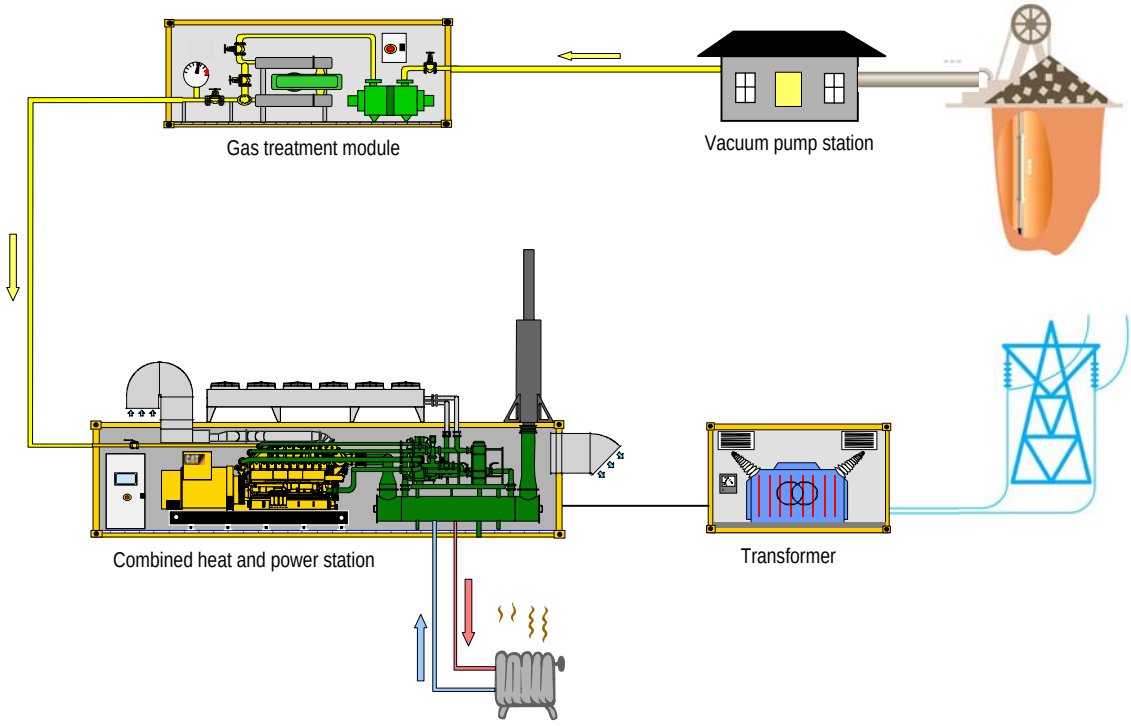
In CBM, degasification systems, commonly referred to as gas drainage systems, are used. Vertical or horizontal wells are drilled into the coal bed and a vacuum is applied to the well to extract the methane (see Figure 6). Compared to VAM, the quality of the methane in this type of extraction is often very high, with methane content above 85 percent being common, especially from vertical wells drilled into the coal seam well ahead of the actual mining.

Figure 6. Coal Gas Extraction



When CMM is removed from the ground, it should be pretreated for use in reciprocating gas engines. Pretreatment includes filtering the CMM for dust and particles through filters, drying the gas to below 80 percent relative humidity and sending the CMM through a fuel train, where the pressure is regulated to between 5 and 35 kPa. After pretreatment, the CMM comes to generator sets, managed with switchgear to provide synchronization, voltage checks, loading and unloading of the engines and overall system protection. Figure 7 provides an illustration of a typical layout of a CMM-fueled generator set system.

Figure 7. Typical CMM Plant Layout



Caterpillar offers the G3520C low energy fuel generator set for use with CMM and other methane fuels found in landfills, digesters, and low-energy biogas environments. Operating at 50 Hz, the new generator set includes equipment that optimizes the performance of engines in parallel-to-grid, continuous-operation applications.

The generator set was specially designed to handle fuel methane concentration variations typical of CMM operations. The G3520C-CMM package is also designed to efficiently and reliably use fuel gas with lower than typical methane content. Special genset configuration can be made for applications with methane content down to 25 percent. Furthermore, VAM with up to 3 percent by volume of methane can be used as combustion air as long as necessary steps are taken for pretreatment meeting Caterpillar's combustion air specifications.

Equipped with a gas engine control module using ADEM™ III electronic controls, the generator set allows for full engine control from a single source. The advanced Air/Fuel Ratio Control is designed for use without an oxygen sensor, allowing as high as a 19.2 bar BMEP rating that supplies high power density while meeting NO_x emission levels of 500 mg/NM_3.

An optional NO_x level of 250 mg/NM_3 is also available through a 54°C separate circuit aftercooler system that can be used with a conventional cooling system arrangement in almost all geographic locations. This option provides greater emissions control for those projects that must meet stricter local regulations or for project owners interested in pursuing carbon trading opportunities.

The Cat® G3520C operates at 1,500 rpm with a continuous rating of 1,966 ekW under standard operating conditions. An open combustion chamber design allows it to operate using low-pressure gas supplies of just 5 to 35 kPa (0.7 psi to 5 psi). The low boost pressure requirement reduces the installation cost of fuel treatment systems often found in low-energy fuel environments.

As shown in Figure 8, the generator set can utilize CMM fuel from a range of 25 percent to 100 percent methane, so the equipment remains efficient throughout the life of a coal mining project.

In order to compensate the pressure drop across the gas train, the generator set would require a gas supply pressure between 40 to 60 kPa, with less than 0.69 kPa for steady-state or 4.83 kPa for transient per second of fuel pressure rate of change at the entry of the fuel train system.

Figure 8. Fuel Treatment and Specifications for Coal Mine Methane Applications

G3520C CMM Fuel Specification				
Parameters		**Unit**	**Min**	**Max**
Concentration		volume %	25	100
Supply Pressure at Engine Inlet		kPag	5	35
Supply Pressure at Fuel Train Entry		kPag	40	60
Rate of Change of Supply Pressure	Steady-State	kPag/sec		0.69
	Transient	kPag/sec		4.83
Particulates (Beta 200)		µm		5
Relative Humidity		%		80

CMM power plant development typically requires 12 to 18 months from start to completion. Duration very much depends on the site accessibility and the preparation and complexity of the power plant. For mobility and ease of installation, some generator set can be offered as containerized sets, which can shorten the completion period.

When considering CMM generator set projects, perhaps the most important decision is choosing a generator set manufacturer. The manufacturer should support customers with design, service, logistical and technical support, and financing. An understanding of local needs and economics and the ability to provide fast, direct service and support are crucial to the success of CMM generator set projects. The manufacturer and dealership staff must also be highly qualified to meet customers' needs for any project, including those like CMM plants with unique needs. A manufacturer that provides financing support and payment options can also be helpful when considering necessary capital investments.

There is considerable opportunity for growth of electric power applications using CMM. Caterpillar's experience in this type of power generation has been proven successful at several sites in China, Australia and UK.

Project Example: Jincheng Anthracite Mining Group, Shanxi Province, China

The Jincheng Anthracite Mining Group, Inc., located in Shanxi Province, China, produces high-quality anthracite coal at several mines that generate substantial volumes of methane. In 1995, methane from seven CMM wells was used to fuel a power plant with a capacity of 1.6 megawatts (MW).

In early 2002, the company increased the capacity to 4 MW by building a second CMM-generated power plant. Together, the power plants reduce greenhouse gas emissions by about 40,000 tons of carbon equivalent per year. Based on its success thus far, the Jincheng Group has developed at the Sihe Mine a third CMM power plant, with 120 MW generating capacity based on Caterpillar internal combustion engines. The project utilizes the latest technologies to boost CMM to fuel this power plant, which generates electricity and heat for use at the mine. In addition, the project provides power for distribution to residential, commercial, and industrial consumers in Jincheng area.

By 2008, the project used at least 166 million cubic meters of CMM per year to serve about 90,000 households and various commercial and industrial establishments in the area. About 410,000 people in Jincheng directly benefit from the cleaner CMM-based energy, reducing indoor and atmospheric pollution. Together, the new power generation capacity and the planned natural gas distribution will avoid emissions of about 500 million cubic meters per year, or 40 MMTCO2E over 20 years.