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INTRODUCTION TO THE GLOBAL COAL MINE METHANE INDUSTRY

(Prepared jointly by the US Environmental Protection Agency and Climate Mitigation Works*)

I. INTRODUCTION

1. For many years, methane in coal seams and surrounding strata, also known as coalbed methane or coal seam gas, was viewed in an unfavourable light. The mining industry considered it a nuisance and safety hazard that threatened lives, equipment and operations while inhibiting mine productivity. For natural gas exploration and production, coalbed methane (CBM) represented an "unconventional" gas resource that was difficult and expensive to produce. In a number of countries, the gas resource base is high, but the low permeability and unique gas reservoir characteristics typical of many coal seams add a level of complexity that has not been cost-effective to overcome.

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2. Even with these inherent difficulties, efforts to capture CBM and coal mine methane (CMM) began as early as the late 1700s when a British scientist drove a metal pipe into a coal seam and produced methane for use in his laboratory. This "well" is considered by some to be the birth of the modern industry. By the early 1900s several European countries were beginning to capture methane from coalmines, and it was the mining industry that began the modern CBM/CMM industry. By the 1950s and 1960s CMM recovery had begun in other countries. Today many countries are interested in this significant resource for a host of uses, such as gas pipeline injection, illumination, boiler fuelling, and electricity generation.

3. Technological advances, favourable government policies, concern over climate change, increasing fuel prices, and improved technology transfer and cooperation have all served to increase recovery of this valuable resource. No longer viewed as annoyances or cost-prohibitive resources, CBM and CMM are now thought of as economically viable commodities that generate revenues or cost savings to projects. Beyond project-specific economic benefits, CMM production yields other important benefits, ranging from reductions in greenhouse gas emissions to improved mine safety to enhanced mine productivity. In many countries with developing economies and economies in transition, their recovery and use provide the basis for important economic and social development, further extending the benefits.

II. COALBED METHANE AND COAL MINE METHANE

4. CBM is formed during coalification, the process that transforms plant material into coal. Organic matter accumulates in swamps as lush vegetation dies and decays. Over time, sediments are deposited over the decayed organic matter. As the thickness of the overlying sediment increases, so does the temperature. This creates physical and chemical changes to the organic matter, resulting in the formation of coal and the production of methane, carbon dioxide, nitrogen, and water. As heat and pressure increase, the carbon content, or rank, of the coal increases. Generally, the deeper and/or higher the rank of the coal seam, the higher its methane content. Coalbeds generally do not release this methane to the atmosphere unless produced by a well, exposed by erosion or disturbed by mining.

5. CMM is the name given to coalbed methane that is released due to mining activities. Thus CMM is a subset of CBM. In the United States, CBM production accounts for about 8% or 44 billion cubic metres (Bm^3) of the country’s annual gas production. CMM is 3% of total CBM production, approximately 1.1 Bm^3 (US EPA 2003). The distinction between CBM and CMM is critical. CMM, when emitted to the atmosphere, is a GHG.

6. Methane’s presence in the earth’s atmosphere affects the planet’s temperature and climate system. Methane’s chemically active properties have indirect impacts on global warming, as the gas enters into chemical reactions in the atmosphere that not only affect the period of time methane stays in the atmosphere, but also play a role in determining the atmospheric concentrations of tropospheric ozone and stratospheric water vapour, both of which are also GHGs. These direct and indirect effects make methane a large contributor to global climate change, contributing 18% of global GHG emissions, second only to carbon dioxide (CO_2). When considered over a 100-year time frame, methane is 21 times as potent as CO_2.

7. Coal mines are one of the major anthropogenic sources of methane emissions, along with landfills, natural gas systems, and the agricultural sector. CMM generate 8-10% of US and global methane emissions. In 2000, US EPA estimates US CMM emissions from all sources (i.e., underground and surface mines, and post-mining emissions) were 4.3 billion cubic metres (Bm^3). This is the equivalent of almost 61 million metric tonnes of CO_2 ($MMTC0_2e$).

III. BENEFITS OF RECOVERING CMM

8. Capture and use of CBM and CMM have many benefits including:

- global environmental benefits through the reduction of greenhouse gases;
- improved air quality through use of a cleaner energy source
- increased mine safety;
- energy independence;
- increased mine productivity; and
- generation of revenues or cost savings.

9. Because CMM projects reduce GHG emissions, they may be eligible for emissions trading programmes. The UNECE paper "Potential for Economies in Transition to Leverage Kyoto Flexible Mechanisms: General Considerations for Coal Mine Methane" (ENERGY/GE.1/2003/5) considers how the Kyoto Protocol's "flexible mechanisms" may encourage more CMM projects in Eastern Europe.

IV. RECOVERY TECHNOLOGIES FOR CMM

10. Recovery technologies are dictated by the purpose of the methane recovery and the geologic strata or mine void containing the gas and are generally differentiated into two distinct categories:

(i) Vertical or horizontal drilling to recover methane from virgin coal seams (i.e., those that have not been disturbed by mining or other activity) either unassociated with mining or deployed in advance of mining

(ii) Vertical and horizontal wells drilled to recover methane after mining has occurred.

(a) <u>Pre-Mine Drainage</u>

11. Because coal seams and surrounding strata are tight and have limited permeability, typical gas well configurations are not cost effective. A variety of drilling techniques, however, have been developed and are being used to produce CBM from virgin coal seams. Wells can be drilled vertically from the surface or horizontally within the mine; vertical wells will typically have higher recovery efficiencies than horizontal wells.

- Vertical fracturing wells: The predominant drilling technology is vertical well fracing. Wells are drilled vertically from the surface and then a substance, such as water, is injected at high pressure into the coal seams to fracture the seam. The water is pumped out, and the gas flows to the well. This technique is effective for deep, gassy wells with limited permeability.

- Directional drilling from the surface: Slant hole drilling and other directional drilling methods are being tested and used in limited instances in CBM production. Vertical wells from the surface are directionally drilled to drain the coal seam horizontally.
- In-mine horizontal boreholes: This technology involves drilling short – or long-hole boreholes horizontally into the seam prior to mining. The introduction of steerable motors in recent years has improved the recovery efficiency of this technique. Of the pre-mine technologies, in-mine horizontal boreholes have the most immediate and direct impact on reducing coal mine methane emissions. However, overall recovery efficiencies are not as strong as vertical well drilling over the long term.

12. The gas produced from un-mined coal seams is usually very high quality, near 100% methane, and is suitable for any application.

(b) Post-Mining Drainage

13. As coal seams are mined, methane from the fractured zone is released into the mined void. Methane becomes explosive at 5%-15% volume; therefore, for safety reasons, this gas must be removed from the mines. To do this, the mines employ very large fans to move large volumes of air through the mine shafts to keep the methane at non-explosive levels, usually less than 1%. Very gassy mines supplement their ventilation systems with degasification systems (also referred to as drainage systems). The mine drainage systems employ a variety of techniques to remove gas after mining has occurred.

- Vertical gob wells. Vertical wells are used to remove gas from the coal seams before mining occurs. Wells are drilled to a depth above the coal seam to be mined. After the area under the well is mined through, the walls and roof collapse and gas fills the fractured zone. Gob wells are used to remove the gas remaining in the gob area.
- In-mine horizontal gob wells. These effectively serve the same purpose as vertical gob wells.
- Cross-measure boreholes. Boreholes are drilled at angles and cross-measured above and/or below the mined seam. In Europe, cross-measure boreholes are the common alternative for removing gas from mined out areas.
- Superjacent method. This technique, also used in Europe, injects gas from the mine to an unused mined out roadway in a coal seam above or below the seam being mined.

14. Gas from post-mining activities generally has high methane contents initially, but, as air mixes with the gas, the methane quality is reduced to 30%-80%. Gas of this quality is desirable for power production, heating, coal drying, boiler fuelling, and for use in industrial processes.

(c) Abandoned Mines

15. Abandoned underground coal mines also generate methane, and can vent enough gas to make recovery a profitable alternative. The technologies used to recover gas from abandoned mines are similar, with some adjustments, to those utilized for pre- and post-mining drainage. In many cases, abandoned mines will be sealed with a vent pipe installed to naturally vent methane. A vacuum pump can be installed on the vent pipe to pull gas out of the mine at increased rates.

V. MARKETS FOR COAL MINE METHANE

16. CMM is used in a variety of conventional applications such as power production and pipeline injection. In an effort to expand the use of CMM, EPA is focusing much of its efforts on promoting new markets for CMM. Much of the US EPA's Coalbed Methane Program's work in the last two years has centred on encouraging mine operators to capture and use the methane in ventilation air.

(a) Conventional Markets

17. To date, almost all CMM recovered in the US and globally can be found in conventional markets. Existing markets consist of a variety of uses comparable to the markets for natural gas. The determining factors as to the best use of the gas are dependent upon many factors including country, geographic location within a country, proximity to natural gas pipelines, proximity to potential industrial users and power plants, quality of the gas, and, in some instances, government support.

18. The most common use for CMM in the United States is pipeline injection. Electricity prices are cheap in the United States, making power production a less feasible alternative. Pipelines require very high quality gas (usually 95% methane), so generally only gas from wells drilled in advance of mining into virgin seams is utilized for this option. However, lower quality methane can be treated and improved to meet pipeline specifications. Jim Walter Resources in Alabama is employing a BCCK nitrogen rejection and cryogenic processing facility to upgrade 72 million m^3 per year of lower quality gas into 41 million m^3 of pipeline-quality gas. Australia and the United Kingdom also capture CMM for pipeline use.

19. In Europe and Japan, power production is the most popular option. Much of the gas now produced in these countries is from abandoned mines or post-mining drainage and is contaminated with air, making it generally unsuitable for pipeline injection without very expensive treatment. US EPA studies have shown that concentrations as low as 30% methane are all that are necessary to generate power. Australia, China and the United States also have several planned power projects.

20. In addition to power production and pipeline injection, CMM is also used in industrial processes, as on-site or local boiler fuel, for coal drying, and as vehicle fuel. All of these alternatives provide good markets for gob gas and gas from abandoned mines because they do not require high methane quality. CMM is used for many of these purposes in economies in transition.

(b) New Markets

21. For the United States, EPA has targeted new markets to expand recovery of CMM, and has promoted these technologies in other countries.

(i) Gob Well Flaring

22. Drained gas can also be flared. In some instances it is simply not yet economically feasible to recover and use drained gob gas. Either the mine is too far from a pipeline, or power production or other uses are not economic. In these instances, an alternative is to flare the gas.

23. Although it may not be the best use of the gas, flaring does reduce the greenhouse gas emissions and is a low cost technical option. Currently there are operating CMM flares, in Australia and Kazakhstan, as well as flares at an abandoned mine in the USA. A major barrier to the deployment of flares has been and continues to be concerns by regulators and mine operators regarding the safe operation of a flare over an operating mine.

(ii) Ventilation Air Methane (VAM) Recovery Technologies

24. Each year underground coal mines throughout the world emit over 16 Bm^3 of methane from their ventilation systems. In terms of global warming potential, that amount is equivalent to over 230 million metric tons of CO_2. Due to recent technological developments, a substantial portion of these emissions could be reduced cost-effectively.

25. Coal mining releases methane from the coal and adjacent rock. Because methane is explosive in air in concentrations ranging from 5 to 15%, safety requires removal of methane released during mining. Gassy mine operations employ large ventilation systems to draw clean air into and through the mine to dilute and remove methane. Although the concentration of methane contained in these ventilation air flows is quite low (typically less than 1%), the volume of air that the systems move into, through, and out of the mine is so large that ventilation systems constitute the single largest source of methane release to the atmosphere from underground coal mines. A typical shaft at a gassy mine in the United States will move between 100 to 250 cubic metres per second of ventilation air.

26. New technologies for oxidizing VAM are ready for commercialization. These technologies can oxidize VAM with or without productive use of the resulting thermal energy.

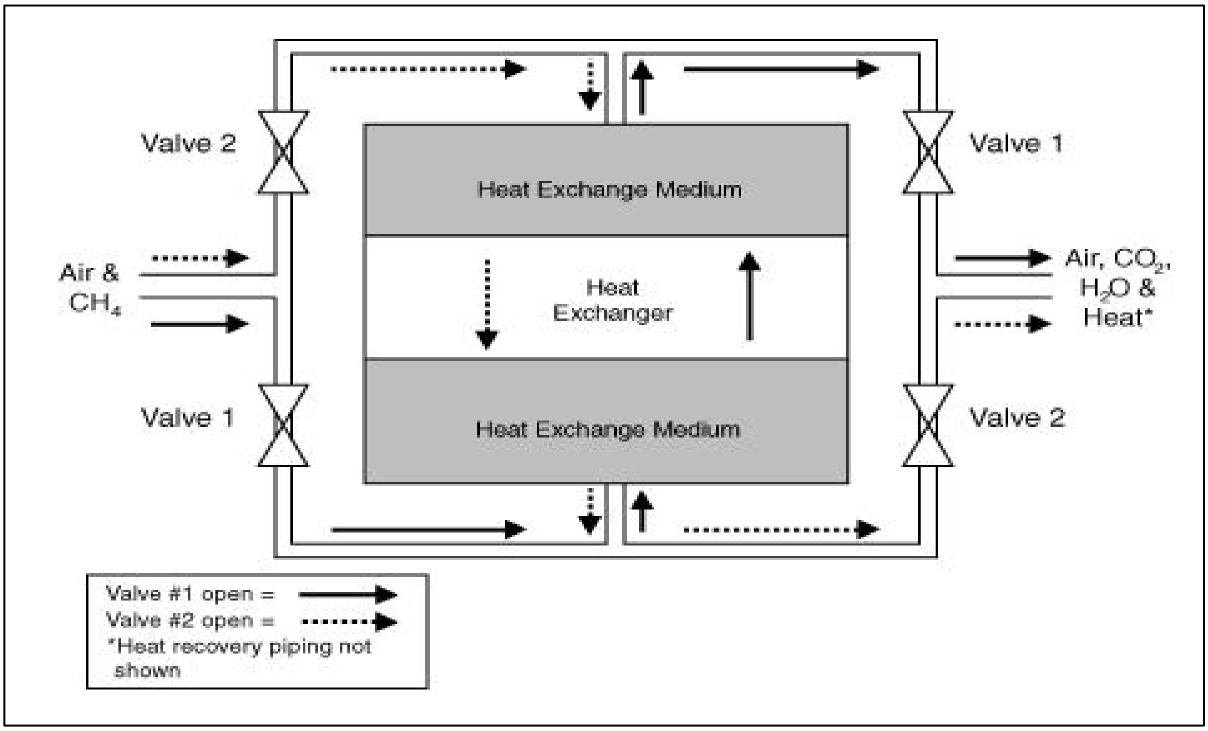
a. Flow-Reversal Reactors

27. The Thermal Flow-Reversal Reactor (TFRR) is a simple apparatus (see Figure 1) that consists of a large bed of silica gravel or ceramic heat exchange medium with a set of electric heating elements in the centre. Airflow equipment such as plenums, ducts, and valves supply VAM to the bed. The process employs the principle of regenerative heat exchange between a gas (ventilation air) and a solid (bed of heat exchange medium selected to store and transfer heat efficiently) in the reaction zone.

28. To start the process, electric heating elements preheat the middle of the bed to the autoignition temperature of methane (1000 °C). During the first half of the first cycle, ventilation air at ambient temperature enters and flows through the reactor from one side. Methane oxidation takes place near the centre of the bed when the mixture exceeds the autoignition temperature of methane. Hot products of combustion and unreacted air continue through the bed, losing heat to the far side of the bed in the process. When the far side of the bed becomes sufficiently hot and

the near side has been cooled by the inflowing ambient-temperature ventilation air, the reactor automatically reverses the direction of flow. New ventilation air enters the far side of the bed and becomes hotter by taking heat from the bed. Close to the reactor's centre, the methane reaches autoignition temperature, oxidizes, and produces heat to be transferred to the near side of the bed before exiting. Temperature at the core reaches 1832 °F (1000 °C) plus the adiabatic temperature rise, and then decreases as the heat exchanger removes heat from the unit.

Figure 1. Schematic of Thermal Flow-Reversal Reactor



29. TFRRs have been employed at thousands of locations throughout the world, primarily for destroying organic contaminants. Two facilities have operated exclusively on ventilation air (one with hot water heat exchange), and about 200 other units use dilute natural gas as a support fuel to supplement concentrations of target compounds (e.g., industrial VOCs). The USA-based company MEGTEC is pursuing full-scale demonstrations of its TFRR technology on VAM at underground coal mines in both Australia and United States.

30. Natural Resources Canada's CANMET research organization has adapted thermal flow-reversal technology to develop their CH4MIN catalytic flow-reversal reactor (CFRR) expressly for use on coal mine VAM. By including a catalyst in the reactor core, CANMET has developed a system that has the same basic design and operation as the VOCSIDIZER , but that oxidizes mine ventilation air at lower temperatures. CANMET has awarded a license to commercialize the CH4MIN system.

b. VAM as Ancillary Fuel

31. Ventilation air methane may also be used as combustion air for power projects. This approach is technically straightforward and commercially proven, but the GHG reduction potential is limited since it requires the siting of large, capital intensive power projects close to ventilation shafts. The Appin Colliery in Australia used approximately 10% of its VAM as combustion air for a series of internal combustion engines. Another ancillary fuel use is soon to be undertaken at a large coal-fired boiler in Australia.

32. One novel approach that has been developed is a plant that co-fires waste coal and VAM in a rotary kiln. For the demonstration, the captured heat shall be used to power a 1.2 MW gas turbine. Depending on the quantities of coal versus VAM used, this plant is either a VAM ancillary or a VAM primary technology. Unlike the lean fuel turbine approaches, it does not require supplemental gas to increase the methane concentration of VAM to sustain operations.

c. Lean-Fuel Turbines

33. Several companies have or are developing technologies to employ VAM in gas turbines as a significant or even primary fuel source. Some of the technologies employ catalysts for the VAM combustion, while others take place in an external combustor without catalysts but at a lower temperature than with normal turbines. To date, the technology vendors claim that they can use VAM (or a mixture of VAM and higher concentration gas) down to concentrations of between 1% and 1.6%, but several are researching means of lowering the required concentration to .8% or below. Depending on the VAM concentration, these turbines may use VAM for over 80% of all fuel if methane concentrations are high, or less than 20% with low VAM concentrations.

34. The above technologies require further assessment before knowing precisely which to employ in different circumstances. Table 1 shows that the application and viability of the different options depends on the methane concentrations in the ventilation air and on other site-specific situations. Clearly, however, if there is a sufficient revenue stream available for the energy or greenhouse gas reductions produced from the oxidation of ventilation air methane, then these projects make economic sense.

Table 1. Comparison of Different Ventilation Air Methane Mitigation Technologies

Technology	**Expected Niche**
VAM as Ancillary Fuel	0% – 1%+ CH_4, where VAM close to large gas or coal fired plant
Flow Reversal Reactor	0.15% – 1%+ CH_4, may be used as flare or for power production
Lean Fuel Turbines	1%+ CH_4 or with supplemental gas available, where power price is favourable
Hybrid VAM/Coal Rotary Kiln	0 – 1%+ CH_4, where waste coal is available

VI. THE GLOBAL MARKET FOR COAL MINE METHANE

(a) Overview of the Global Marketplace

35. The global potential for CMM is quite large, but is directly affected by a number of factors. The price of gas and electricity prices and the quality and reliability of the infrastructure to deliver gas or electricity are very important. It will only be economically feasible to recover CMM if the cost of production is lower than the revenues or avoided costs generated by projects with an acceptable rate of return. Also affecting markets are government/bilateral/multilateral aid and subsidies to increase incentives to produce CMM. In the United States for example, the Section 29 Tax Credit helped spur significant increases in CBM/CMM production. In many developing countries and economies in transition, foreign monetary, technical, and policy aid such as the Global Environment Facility provide the foundation for successful projects.

36. Table 2 shows CMM emissions in 2000 and projected for 2010 for most countries with significant underground mining activities. The table also shows the equivalent carbon dioxide emissions. With the exception of Australia, emissions from the industrialized countries are expected to decrease or remain steady compared with emissions in developing countries, especially China and India, which are expected to increase significantly. One important note here is that abandoned mine emissions are not included in the emission inventories. In countries such as the United States, United Kingdom, Germany, and Japan, abandoned mine emissions are likely to increase the countries' total CMM emissions.

Table 2: Coal Mine Methane Emissions for Selected Countries, 2000 and 2010

Country	2000 CH_4 Emissions (Million m^3)	2000 CO_2 Equivalent (MMT)	2010 CH_4 Emissions (Million m^3)	2010 CO_2 Equivalent (MMT)
Australia	1,381	19.7	2,004	28.6
Canada	98	1.4	91	1.3
China	10,000	142.7	15,753	224.7
Czech Republic	351	5.0	266	3.8
Germany	1,030	14.7	764	10.9
India	683	9.7	1,319	18.8
Japan	133	1.9	147	2.1
Kazakhstan	488	7.0	447	6.4
Poland	1,037	14.8	939	13.4
Russia Federation	2,236	31.9	2,138	30.5
South Africa	496	7.1	506	7.2
Turkey	123	1.8	184	2.6
Ukraine	1,970	28.1	1,689	24.1
United Kingdom	365	5.2	343	4.9
United States	5,461	77.9	5,748	82.0

(Sources: U.S. EPA. 2001. *Non-CO2 Greenhouse Gas Emissions from Developed Countries: 1990-2010*. Sept. 2001. EPA-430-R-01-007 and country reports)

37. US EPA has analyzed the global market for VAM. The report finds that of the total of 237 million metric tons of CO_2e VAM emissions (16.6 Bm^3 of methane), with a net project cost of US$3.00 per tonne of CO_2e and with average industrial power prices, approximately 172 million tonnes of CO_2e could be oxidized. The analysis shows that the quantity of emissions that may be mitigated at lower costs is much less: at US$2.00 per tonne, approximately 60 million tonnes of CO2e could be mitigated (EPA, 2003).

38. Some general observations can be made with respect to specific regions. The North American market (United States and Canada) has an advanced and mature CBM/CMM market with many projects and many technical experts.

39. Western Europe, especially Germany and the United Kingdom, Japan and Australia also have sophisticated CBM/CMM markets, and are very innovative. Much of the work in Western Europe and Japan in the future will focus on CMM extraction from closed/abandoned mines. These countries also have strong government support, either directly or indirectly, for project development.

40. Considerable potential for CBM exists in Asia. China has very large reserves and the government is solidly in support of CBM development. The country's CBM resources have attracted attention from major oil and gas companies. India is also promoting its CBM/CMM resources and is receiving interest as well. Kazakhstan is also encouraging CBM development. Although risks are inherent in these countries, their licensing systems are familiar to western investors. As a result, they appear to be generating greater interest.

41. Eastern Europe, Russia Federation and Ukraine all have established and large coal mining operations with gassy mines. Even though bilateral and multilateral financial institutions such as the World Bank have encouraged these countries to restructure their coal industry in recent years by closing unprofitable mines, little progress has been made. As a result, many gassy mines are still open. There is very limited CBM production, but all of these countries have experience with degasification and use of CMM. These regions, however, need investment to procure modern drilling and recovery technologies and improved infrastructure to maximize their CBM/CMM capabilities. Due to higher risks, though, investment is limited.

42. In the following section, brief country-specific profiles are provided on CBM/CMM activities in a select number of countries.

(b) Country-Specific Profiles

(i) Australia

43. Australia has a very advanced CMM-industry, and is a leader in innovation and creativity. The Australian government and Australian corporations are very proactive in encouraging and experimenting with new technologies. The projects below describe some of the ongoing activities in the country:

- At the Appin Colliery in New South Wales, BHP Billiton has teamed with Megtec Systems to operate a thermal flow reversal demonstration project with the Vocsidizer® to combust ventilation air methane.

- At the Appin and Tower Collieries, CMM is used to produce 94 MW of electricity from 651,000 m^3 of drained gas per day. At Appin the project's engines also consume mine ventilation air as combustion air. Energy Developments, operator of this project, also is demonstrating a lean fuel gas turbine which may use ventilation air methane for much of its fuel needs.
- Capricorn Coal Development Joint Venture (Capricorn) commissioned a gob well flare at the Central Colliery in Queensland in 1998.
- In October 2001, the Australian Government awarded US$15 million in grants to three CMM projects expected to cut greenhouse gas emissions by 7.2 million tones between 2008-2012.

(ii) China

44. China has the largest CMM emissions in the world, and presents great opportunities for CMM production. CMM development is also very important for China because Chinese coal mines are some of the most dangerous in the world, in great part because of their high methane levels. As a result, the Chinese government has made a very strong commitment to CMM development.

45. The country has long been active in utilizing its CMM resources. Underground methane drainage began in China in the 1950s. Surface CMM development began in the 1990s. As of 1999, 184 coal mines in China have drainage systems in place. (Huang et al November, 2001). In 1999, 728 million m^3 of methane were drained, of which 400 million m^3 were used. The majority of CMM is used for distribution to residential users, power generation, and as feed-stock for chemical production (EPA CBM Extra February 2001). Many coal mines are located near markets, and the completion of a major natural gas pipeline will add significant capacity for CMM transport.

46. Because of the large resource base, high gas content and potential markets, there is considerable interest in China. The list of projects below highlights recent activities and planned projects:

- GEF Project in mid 1990s at Tiefa, Songzao and Kailuan mines demonstrated improved methane drainage techniques. Project total was US$10 million.
- The Asian Development Bank has allocated $150-200 million for China CBM/CMM projects.
- Jincheng Coal Mine Administration – Preliminary plans call for 120 MW CMM-fuelled power plant using 240 million m^3 per year.
- The United Kingdom Department of Trade & Industry (DTI) Cleaner Coal Technology Programme has launched a series of collaborative CBM/CMM projects in China.
- JCOAL/APEC project at Tiefa Coal Mine Group in Liaoning Province has recently been completed that drains gas for delivery to nearby Tieling City as a municipal gas supply.
- Since 1994 EPA and the China CBM Clearinghouse have collaborated to promote CMM recovery. Now both organizations are focusing on helping companies to commercialize CMM projects and investigating potential for ventilation air methane use projects.

(iii) Czech Republic

47. The Czech Republic has a long history of CMM utilization. Since the early 1900s, several mines in the Upper Silesian (Ostrava-Karvina) Basin have produced and utilized CMM from in-mine boreholes and abandoned mines. Today, approximately 100 million m^3 per year (nearly 90% of drained gas) is captured and used in the Basin (Takla 1995). DPB Paskov AS is the leader in the Czech Republic in CMM development. It has been active since 1992 in CMM development and also owns and operates a 200 km pipeline.

48. Declines in North Sea natural gas imports and potential upward pressure on Russian natural gas prices could increase demand for alternative sources, including CMM. The Czech government recognizes the potential benefits of CBM/CMM and has supported its development through direct funding and implementation of a favourable leasing policy.

(iv) Germany

49. Like other Western European countries, Germany has a long history of CMM use. In 1952, a 100 MW power station was constructed using CMM. Also like other Western European countries, Germany is experiencing mine closures. But like the British, German companies have since 2001 developed in excess of 30 CMM-fuelled power projects, and Germany is a leader in the use of CMM for combined heat and power.

50. The German government has recognized the important role of CMM as a clean energy resource by passing the Act on Granting Priority to Renewable Energy Sources. Under this law, CMM is considered a renewable resource and installation of small electric generators that run on CMM is eligible for a US$0.07 per kilowatt-hour payment.

(v) Poland

51. Poland is one of the world's major coal producing countries and it has developed expertise in CMM recovery. Degasification operations in Polish mines use a combination of cross-measure boreholes to produce gas in advance of mining and in-mine gob wells to drain mined-out areas. Approximately 70% of gas recovered from degasification systems is used in conventional markets including power generation, heating, coal drying and industrial applications. The coal industry in Poland has moved through various stages of restructuring and many gassy coal mines have shut down in recent years. However, there continues to be interest and activity developing coal mine methane fuelled power projects and a feasibility study funded by the United States Trade and Development Agency is now exploring the potential for using ventilation air methane.

(vi) Russian Federation

52. Although coal production declined significantly in the 1990s, the Russia Federation remains the third largest emitter of CMM with annual emissions of over 2.2 Bm^3. Most Russian CMM can be found in two basins: Kuzbass in western Siberia and Pechora in arctic European Russia. There is limited use of drainage systems in the Russian Federation even though many mines are gassy. CMM that is recovered is used for on-site heating and boiler fuel. A project sponsored by the Global Environment Facility has been approved and will include the creation of a service company to drain and use CMM in the Kuzbass Basin. The regional and national governments are supportive of CMM developments.

53. The International Coal and Methane Centre - Uglemetan was established in Kemerovo in the Kuzbass Basin to promote CBM/CMM development and to provide technical services to the mining concerns and energy developers interested in recovering these resources in the Kuzbass. The Centre has equipment and expertise to assess key CMM reservoir parameters such as gas content, permeability, and in-situ stress using United States purchased equipment.

(vii) Ukraine

54. There is much opportunity for CMM development in Ukraine since many of its mines are located in or near the major population centres of Eastern Ukraine and many are deep and very gassy. Mine safety is a significant problem in Ukraine, and the country is second to China in the number of deaths per million tonnes of coal mined. Currently, the country imports 76% of its natural gas needs, and CBM/CMM could enhance Ukraine's energy security.

55. Coal mines in Ukraine have experience in degassing mines and recovering the gas. In 2000, 45 mines employed degasification systems, and 12 recovered the CMM to use on site (PEER 2001). The principal application of CMM in Ukraine is boiler fuel on-site at the mines.

56. Ukraine CBM/CMM opportunities have been explored in great detail. Many different organizations have completed feasibility studies. The investment climate for Ukraine is challenging at this time, although the economy is improving. Most observers are waiting for a demonstration-scale pilot project to be implemented. In Ukraine, the Partnership for Energy & Environmental Reform (PEER) promotes CMM opportunities. PEER has completed a handbook on opportunities for development of CMM in Ukraine, and has also developed business plans for two of the mines, the Komsomolets Donbassa and Skochinsky mines.

(viii) United Kingdom

57. The United Kingdom has a long history of CMM utilization and has an advanced and innovative industry. As elsewhere in Western Europe, the coal industry has experienced a major restructuring, and most mines have closed or will be closed. In the aftermath of the restructuring, though, United Kingdom project developers have found an excellent resource in the closed mines. CMM utilization has taken off with several projects implemented and many more planned. Currently eight abandoned mine projects in the United Kingdom are producing 35 MW of electricity and are delivering gas to two local distribution companies (Davies, 2003). There are also two projects at operating mines using CMM commingled with natural gas to generate 22 MW. Plans had called for more electricity to be generated from abandoned mine methane by 2004 (UK DTI 2001), but recent drops in power prices are slowing down progress.

58. The United Kingdom Department of Trade & Industry (DTI) Cleaner Coal Technology Programme encourages and promotes the use of CBM/CMM in the United Kingdom, and the Association of Coal Mine Methane Operators (ACMMO) is an industry organization that promotes policies to encourage coal mine methane investments.

(ix) United States of America

59. The United States is the second largest emitter of CMM and uses more drained gas than any other nation. Although several other countries began capturing CMM long before the United States, it began vigorous efforts in the 1970s to drain coal seams ahead of mining and has since been at the forefront of the industry. The original industry pioneers, CONSOL Energy and Jim Walter Resources, continue to lead the United States in CMM recovery. Other large coal companies such as US Steel Mining, Peabody and Drummond Coal are also recovering drained gas.

60. Over time, the United States has continued to refine and improve drilling technologies. In addition, government support such as the Section 29 tax credit has served to spur increased production. Legislative support for CBM/CMM continues as two bills are currently before the United States Congress to promote their development.

61. The United States industry is mature. In 2000, the United States drained and used 1.1 Bm^3 of CMM, exclusive of abandoned mines. As noted earlier in the report, most gas is used for pipeline injection; however, about 14 million m^3 is used for coal drying. As economics improve, power generation is also becoming a favourable option CONSOL Energy and Allegheny Power now operate an 88 MW power plant.

62. 85%-90% of the CMM drained from coal mines in the United States is being delivered to conventional markets. The future focus in the United States is on new, unconventional markets for CMM. Specifically, EPA is directing much of its efforts to capturing difficult-to-market gas, ventilation air methane (VAM), and abandoned mine emissions.

VII. CONCLUSION

63. Coal mine methane has become a key component in the energy mix for many countries. For the United States, Western Europe, Japan, and Australia, CMM is an important marginal energy resource. Markets in these countries are mature, with well-developed technical expertise and a sophisticated, innovative industry. For other places, such as Asia and Eastern Europe, CMM has additional socio-economic benefits, and many countries, including China, India, and Ukraine, have made very strong commitments to promote development of their CMM resources.

64. In the United States, efforts are being directed at the use of ventilation air methane. CMM production in Japan, Australia, and China is expected to increase substantially in the coming years. Western Europe and Japan will focus on recovery from abandoned mines, with power production likely to continue to be the primary use. Both conventional markets and new markets are available for China, Eastern Europe and the former Soviet Union. China is attracting the most interest with its large resource base and commitment to resource development. Other countries to look for are Mexico, Indonesia, and Vietnam.

65. While the global market for CMM is significant and likely to grow, what remains to be known is how international efforts to curb greenhouse gas emissions will stimulate CMM projects throughout the world. The subsequent paper prepared for UNECE shall explore many of the factors at play between climate mitigation policies and regimes and the CMM markets that may provide low cost carbon credits to comply with caps on greenhouse gas emissions.

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