# Evolution of US Markets for Coal Mine Methane

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**ABSTRACT**

Methane is a potent heat trapping gas and is one of the six gases covered under the United Nations Framework Convention on Climate Change to which the United States is a signatory. The U.S. Environmental Protection Agency (EPA) began exploring options to reduce emissions of methane in 1989 and identified coal mining as a significant global source of both emissions and mitigation opportunities. In 1994, EPA founded the voluntary Coalbed Methane Outreach Program to help US coal operators and other stakeholders identify the technologies, finance sources and markets to develop coal mine methane energy recovery projects. Since then, avoided methane emissions in the US have almost tripled.

This paper outlines the status of coal mine methane projects in the U.S. The paper highlights the key milestones in the development of the US coal mine methane industry. It also identifies and analyzes the reasons for the industry's progress, articulates the challenges faced by the industry, and discusses the key opportunities available for continued growth of the industry.

## 1.0 OVERVIEW/BACKGROUND OF US CMM INDUSTRY

The gassy coal seams of the US can be found in four geographic regions: the Appalachian Basins of the eastern US (medium to high volatile bituminous and anthracite); the Illinois Basin in the Midwest (medium to high volatile bituminous), the Rocky Mountain Basins in the western US (lignite, subbituminous to medium/high volatile bituminous), and the Gulf Coast and Anadarko Basins of the South/Southwest (lignite, subbituminous – medium/high volatile bituminous). Historically, US coal production was centered in the underground mines of the Appalachian Basins, especially the Northern and Central Appalachian Basins. Although the majority of US coal production has shifted to the Western Basins and large surface mining operations, the Appalachian Basins still remain the center of the underground mining industry with seven of the top ten producing underground mines in the US. (EIA 2001). The Illinois and Western Basins also have extensive underground operations.

The US has significant coalbed methane resources. Various sources estimate the CBM resource base at between 4 and 11 trillion cubic meters ($Tm^3$) ranking the US behind Canada, Russia, China, and Australia (Kuuskra 1992, Cairn Point Publishing 1997, Schultz 1998, Potential Gas Committee 2001). In terms of CMM emissions, the US ranks behind China as the second largest emitter of coal mine methane. In 2001, the total methane liberated from underground mines was 133 billion cubic feet (Bcf) or 3.8 $Bm^3$. As shown

in Figure 1, the U.S. produced 40 billion cubic feet (Bcf) or 1.2 $Bm^3$ of the underground CMM liberated which accounted for 2.5% of the US total CBM production of 1.6 trillion cubic feet (Tcf, 45 $Bm^3$). (USEPA 2003a and U.S. Department of Energy 2002) After netting out the 40 Bcf recovered and utilized, net emissions from underground mines were 93 Bcf (2.6 $Bm^3$). In addition to underground mines, emissions also emanate from surface mines and post-mining activities including the transportation, storage, and processing of coal. Adding these sources to the net emissions from underground mines yields a total emissions number of 151 Bcf (4.3 $Bm^3$) in 2001. See Figure 2. (USEPA 2003a)

With this large resource base, the US Government considers CBM and CMM development to be very important to the nation's energy mix, and has divided responsibility for promoting CMM recovery among four agencies. Each of these agencies plays a distinct but complementary role to encourage CMM capture. Two of the agencies focus primarily on the environmental/energy aspects of methane recovery while the other two are concerned with mine safety. The US Environmental Protection Agency (EPA) is charged with providing outreach to identify the costs and benefits of CMM recovery and use and to promote capture as an economically viable and environmentally friendly alternative. Within EPA, the Coalbed Methane Outreach Program was created in 1994 as a voluntary program to coordinate the agency's outreach and technical assistance efforts. The US Department of Energy (DOE) is responsible for supporting research, development, and demonstration projects, and EPA and DOE typically work closely when evaluating innovative technologies. The Mine Safety & Health Administration (MSHA) of the US Department of Labor is the agency with regulatory authority over mining operations. All degasification and utilization plans must be approved by MSHA, and, in some cases, State government authorities. The fourth organization is the National Institute for Occupational Safety & Health (CMM work was formerly undertaken by the US Bureau of Mines), a research organization responsible for designing and evaluating technologies to improve mine ventilation and methane drainage. The four agencies maintain good relations and work closely together when appropriate.

## 2.0 RECOVERY OF DRAINED GAS EMISSIONS IN THE US

Mines in the US have been very successful capturing and utilizing CMM from mine degasification or drainage systems. As noted previously, US mines recovered 40 Bcf (1.13 $Bm^3$) out of the 48 Bcf (1.36 $Bm^3$) of CMM made available by drainage systems in 2001. This represents a market penetration of 80%, and is a dramatic increase since 1990 when the industry captured 14 Bcf (396 million $m^3$) or 27% of the available drained gas. (EPA 2003a) It is also notable that when compared with the other major sources of anthropogenic methane emissions in the US, the coal industry has seen the greatest reduction in emissions. Using 1990 as a baseline year, CMM emissions have declined by 30%, whereas methane emissions from landfills have declined 5%, natural gas systems 3%, and agricultural sources have actually experienced a slight increase. (EPA 2002)

Until recently, about 99% of US CMM used was injected into natural gas pipeline systems. CONSOL also has a coal drying unit that utilizes 500 mmcf (14 million $m^3$) per year. Recent non-pipeline projects include an 88 MW power generation project at CONSOL's VP/Buchanan mines, vent heating at Jim Walter Resources, and a 1.2 MW power generation project at Peabody's Federal No. 2 mine.

There are several reasons for this success:

- There is a strong institutional knowledge in the US. Much of the research, development, and refinement of CMM drainage technology, especially degasification in advance of mining, occurred in the US during 1970's, 1980's, and 1990's.
- Compared with many other countries, mineable coal seams provide a favorable mix of good gas content with reasonably good permeability. In some instances surface conditions are favorable also with flat terrain. This is not the case for the Northern and Central Appalachian basins, but is true for the Warrior Basin in Alabama, the Illinois Basin, and some areas of the West.
- The success enjoyed by the US in CMM/CBM production might not have occurred without the strategic vision of those in the industry. Early on several in industry realized that this waste product had value and sought to identify markets for the gas.
- There is a strong market for natural gas in the US. According to the US Department of Energy, total natural gas consumption in 2001 was 23 trillion cubic feet (651 $Bm^3$) and is forecast to grow to almost 36 Tcf (991 $Bm^3$) by 2025. (US DOE 2003) Helping realize this demand is the extensive and well-capitalized natural gas pipeline network in the US, especially in the eastern third of the country.
- Several operations have also found that it is economical to upgrade gob (also called "goaf") gas by processing it or blending it with higher-quality CMM, CBM, or natural gas to meet pipeline standards. One example is CONSOL's operations at the Buchanan and adjacent VP mines in southwestern Virginia where gob gas is blended with high-quality gas and injected into the interstate pipeline. Another example is Jim Walter Resources' use of the BCCK Nitech cryogenic facility in Alabama. The plant removes nitrogen and other contaminants from gob gas, and the cryogenic process creates 4 million cubic feet (mmcf) per day (41 million $m^3$ per year) of pipeline-quality gas out of 7 mmcf (72 $m^3$ per year) of gob gas.
- The US Government has also actively supported the industry's efforts by providing tax incentives, research and development funding, and technical assistance to encourage greater CBM/CMM production.

## 3.0 BARRIERS TO FURTHER REDUCTIONS OF CMM EMISSIONS

While the US has made impressive gains in utilizing drained gas emissions, there continue to be barriers to further recovery. Generally, the institutional and regulatory barriers have largely been overcome. Most mining companies now accept gas drainage and use as a practical, cost-effective practice. The

challenges today generally revolve around market and, to some extent, legal barriers. For the most part, the remaining volume of drained gas, about 8 Bcf (226 million $m^3$), is generally difficult to market. In many cases, especially in the West, the distance to natural gas pipelines can make a project uneconomical. There are also pipeline capacity constraints that limit access to markets even if a pipeline is accessible. Another option often considered and evaluated is power generation, but few projects have materialized due to low power prices in the US. Generally, I would say $.03 to $.05 per kilowatt hour (kWh) is recognized as the breakeven point for a CMM-fueled power generation project in the US, but in many regions actual power prices are as low as $0.02 per kWh (EPA 2003c). However, as discussed later in this paper, interest in power generation is growing as market conditions make it a more viable option in some areas.

As CBM/CMM production activity has increased in the US, ownership has also become a contentious issue. When the gas is recovered and used generating revenue, claims for royalties are being filed by the owners of the gas estate. Courts in the US have ruled for both the coal and natural gas lease holders. To address the problems surrounding ownership, many coal producing states have moved forward with legislation to clarify the issue on a state-by-state basis. CMM developers are also taking the initiative to move forward and avoid any potential conflicts by purchasing the natural gas rights to a property in addition to the coal rights.

EPA will continue to promote recovery of the remaining drained gas, and the future appears promising. In addition to the 8 Bcf (226 million $m^3$) of drained gas already available, several new mines and some existing mines are planning or have incorporated drainage programs into their mine plans. An EPA analysis identified 4 operating mines in the eastern US and 9 operating and planned mines in the West that would be excellent candidates for CMM projects. The mines are expected to produce up to 60 million cubic feet per day (620 million $m^3$ per year) of ventilation emissions. Other favorable developments include:

- Increased pipeline capacity could provide new avenues to markets. Interstate natural gas pipeline capacity in the West is expected to increase by an additional 2 Bcf (57 million $m^3$) per day by 2003 as two planned expansions and two new pipelines come on line in the Rocky Mountains. (US DOE 2001).
- New technologies such as nitrogen injection, enhanced fracing (e.g. pulse fracing), and directional drilling could increase recovery efficiencies and generate even greater volumes of drained gas. A 10% increase in the recovery efficiency of most mines with degasification systems in place would yield an additional 7 Bcf (198 million $m^3$) of CMM.
- Power generation is being considered more and more in the US. This is especially true in the West where power prices are more favorable and power transmission line interconnects may be more cost effective because the transmission lines are often more accessible than natural gas pipelines. There are two power generation projects in place at active mines in the US, though both are in the East. CONSOL Energy and

Allegheny Power have installed two 44MW gas turbines at the VP/Buchanan mines. Northwest Fuels Development generates 1.2 MW of power using internal combustion engines at Peabody's Federal No. 2 in West Virginia.

- Flaring is another downstream option. For years, the US coal industry did not have a favorable view of flaring over operating mines, but the successful installation and operation of a CMM flare at the Shell Central Colliery in Australia has addressed many of the safety issues.

## 4.0 METHANE FROM ABANDONED MINES

Abandoned mines are another source of medium- to high-quality CMM. In the US, as in Western Europe and Japan, the coal industry has gone through significant restructuring over the last 30 years resulting in the closure of thousands of mines. Many of these abandoned mines were considered gassy when operating, and continue to vent methane after closure.

The coal mine methane emission estimates included in the annual *Inventory of U.S. Greenhouse Gas Emissions and Sinks* (USEPA, 2003a) do not include emissions from abandoned mines (abandoned mine methane or AMM). The IPCC has not approved, adopted, nor endorsed a methodology for abandoned underground mine emissions. However, EPA recognizes that abandoned mines do contribute greenhouse gas emissions; therefore, EPA and Raven Ridge Resources (RRR) have spent several years developing a methodology to estimate emissions from abandoned U.S. underground mines. The results show that abandoned mine emissions in the U.S., while not a large share of overall coal mine methane emissions, increase total emissions by 5-10%. (EPA 2003b) See Figure 3.

There are currently 20 abandoned mine projects in the US pulling gas from 30 closed mines. These projects range from power production using internal combustion engines to gas blending and upgrading for natural gas pipeline injection. There is also a flaring project at an abandoned mine, and an experimental fuel cell that will utilize AMM is being deployed.

Use of AMM is expected to continue growing as many gassy mines have closed in recent years. The mined out void in essence presents the developer with a pre-drilled well, and many abandoned mines are also located near end-use markets. In addition, although developing an AMM project presents many challenges, some developers prefer abandoned mines because they do not have to integrate their programs with mining operations.

## 5.0 VENTILATION AIR METHANE – FUTURE OPPORTUNITIES FOR US CMM RECOVERY AND UTILIZATION

To safely produce coal, gassy underground coal mines need to circulate vast quantities of air to dilute methane concentrations and other substances. Typically, mines need to keep working areas below one percent methane concentration. To date, the vast majority of this ventilation air methane (VAM) vents to the atmosphere, and emissions emanating from ventilation shafts

represent the single largest source of coal mining emissions. EPA estimates 2000 global VAM emissions exceeded 600 Bcf (17 $Bm^3$), the equivalent of 237 million tonnes of carbon dioxide equivalent. (USEPA, 2003c) US VAM emissions in 2001 totaled 86 Bcf (2.4 $Bm^3$) or 35 million tonnes of $CO^2$ equivalent. (USEPA, 2003a).

Until recently, because of the very low concentration of methane in ventilation air, coal operators have had no technically proven means to recover this gas for its energy value. However, over the past decade technologies have been developed and adapted that promise to mitigate most of these emissions at low cost. Now EPA and other organizations and technology vendors are working to demonstrate and commercialize these technologies.

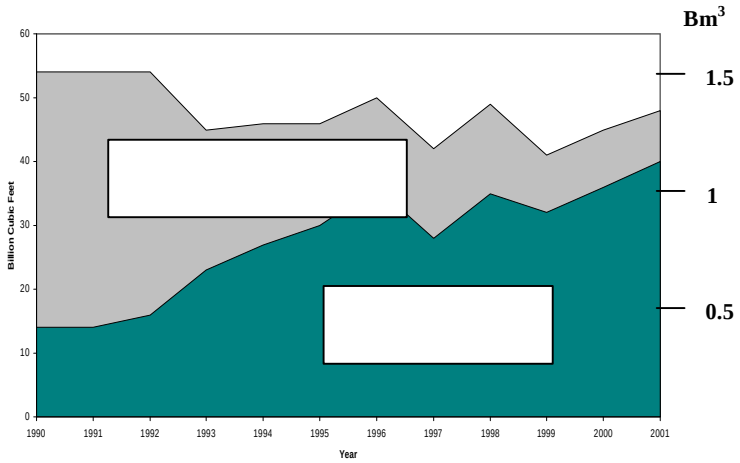
EPA has developed marginal abatement cost curves to evaluate the cost of the VAM technologies. Because the most is known about the oxidation technologies, the costs for the flow reversal reactors were used in the calculations. As Figure 4 shows, at $3.00 per tonne of $CO_2e$ or about $0.12 per kWh, approximately 25 million tonnes of $CO_2e$ could be oxidized in the US. Translating these costs to market size, at $3.00/tonne $CO_2e$ nearly 460 MW of net electric capacity could be developed, and annual revenue could exceed $120 million. Further, revenues generated to meet the equipment needs of the market could substantially increase the overall economic benefits. (EPA, 2003c)

As noted earlier, CMOP's strategic direction is now focused on reductions of ventilation emissions. The Program has committed and will continue to commit significant efforts to finding economic solutions to mitigate this source of methane.

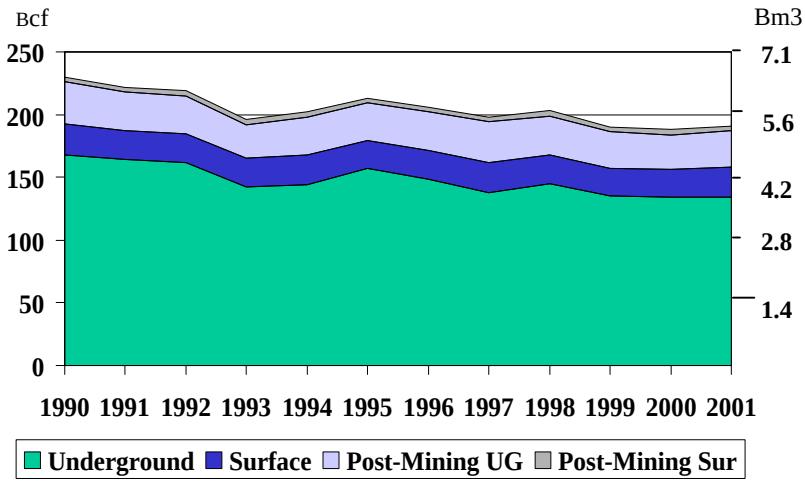
## 6.0 CONCLUSION

The US leads the world in coal mine methane capture and utilization at active mines. In 2000, 80% of all drained gas was used, primarily injected into the natural gas grid. The environmental and ancillary benefits derived from CMM recovery are many, and are proving to be quite profitable for the US companies active in the market. While the market penetration for drained gas is very good, there remain many opportunities for additional CMM projects. In addition to the 8 Bcf (227 million $m^3$) of drained gas available, installation of degasification systems at existing mines and several new mines will likely add to the amount of gas available. Improvements in drilling technologies could further increase the available volumes of drained gas. Abandoned mines represent a new and growing coal mine methane resource. Although the US lags behind UK and Germany in exploiting this resource, the number of abandoned mine methane projects continue to grow as do the volumes recovered. With the advent of technologies that can make use of the low concentration of methane, much of the US Government will now be directed at encouraging VAM project development.

## Figure 1 –US Drained Gas Emissions 1990-2001




## Figure 2 –US Coal Mine Methane Emissions 1990-2001




## Figure 3 – US Abandoned Mine Emissions 1990-2000

**Figure 5: Abandoned Mine Methane Emissions Estimate for 1990-2000**

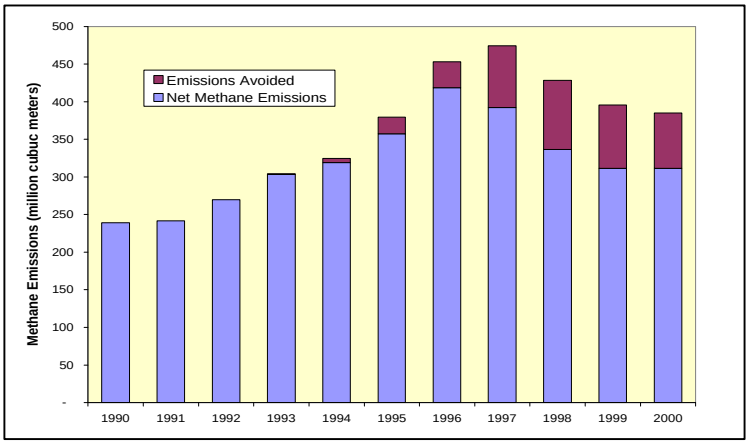
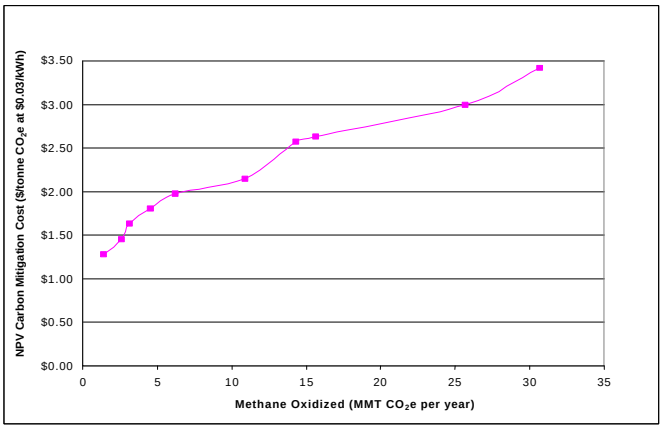


**Figure 4 –US VAM Marginal Abatement Curve**

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