An Analysis of Emissions and Market Potential to Optimize Ventilation Air Methane Mitigation

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Abstract
Methane, a potent greenhouse gas, is liberated from underground coal mines in large quantities. Emissions emanating from ventilation shafts represent the single largest source of coal mining emissions. U.S. Environmental Protection Agency (EPA) estimates 2000 global ventilation air methane emissions exceeded 17 billion cubic meters (600 Bcf), which is the equivalent of 237 million tonnes of carbon dioxide equivalent. The methane emitted from ventilation shafts is necessarily dilute, typically less than one percent. As such, conventional methane use options, such as combustion, are technically unfeasible.

Recent analyses by EPA and others have identified and validated the technical feasibility of a number of options to oxidize ventilation air methane. Prominent among these technologies are flow reversal reaction, where high temperatures in a reactor permit auto-ignition of dilute methane streams. This paper shall summarize research characterizing national-level ventilation air methane emissions and analyze flow reversal reaction's applicability to cost-effectively reduce ventilation air methane emissions. Based on market and costing analyses performed by EPA, at a marginal cost of $3.00/tonne CO_2 equivalent, 172 million tonnes of CO_2 equivalent ventilation air methane may be oxidized globally.

1.0 Introduction

To safely mine coal, gassy underground 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. Almost all of this ventilation air methane (VAM) vents to the atmosphere. EPA estimates 2000 global ventilation air methane emissions exceeded 17 billion cubic meters (600 Bcf), which is the equivalent of 237 million tonnes of carbon dioxide.

Approximately 88 percent of all VAM emissions are found in only twelve countries. China alone is responsible for over one third of all emissions, followed by the U.S., Ukraine, Russia and Australia. Methane concentrations vary from ventilation shaft to ventilation shaft and from country to country. Concentrations in only a few cases exceed 1.0 percent, but in most countries studied some proportion of mine shafts release ventilation air containing over 0.5 percent methane.

EPA and other organizations, plus technology vendors, are working to demonstrate and commercialize these technologies. In the past, coal mine methane produced from degasification wells was not commercially employed, but now in many countries most of it put to beneficial use. Technologies are commercially available and demonstrated to treat most VAM as a viable energy resource. Therefore, it is important both to understand better the resource and the mitigation technologies available, and also to gain hands-on experience with projects that demonstrate the technologies.

This paper will focus on work EPA has performed over the past two years estimating global VAM emissions and the cost of reducing them and gaining an understanding of the global market. EPA is using these studies to help develop strategies to nurture an industry that oxidizes VAM thereby reducing VAM emissions worldwide.

2.0 Ventilation Air Methane Resources

EPA published a report in July 2003 that evaluates the global VAM market. *Assessment of the Worldwide Market Potential for Oxidizing Coal Mine Ventilation Air Methane* (USEPA 430-R-03-002, July 2003) estimates VAM emission flows and concentrations for each of the major underground coal-producing countries. Methane concentrations are the most critical factor in selecting technologies and estimating cost. The report uses country-specific mine data to develop cost estimates for the most universally applicable technology, flow reversal reactors, to determine the size of the market. There are two versions of market size, one based on prevailing power prices and the other on CO_2 equivalent emission reductions.

The report shows that approximately 88 percent of all VAM emissions are found in only twelve countries. As Table 1 demonstrates, China alone is responsible for about 39 percentof all emissions. China's emissions combined with those of the U.S., Ukraine, Russia, and Australia represent about 75% of total VAM emissions. Methane concentrations vary from ventilation shaft to ventilation shaft, and from country to country. EPA received data from in-country experts that give a general idea of the average concentrations and their distribution. Concentrations in only a few cases exceed 1.0 percent, but in most countries studied there were a significant percentage of all emissions with concentrations over 0.5 percent.

3.0 Global VAM Oxidation Market

To understand the size and scope of the global market for ventilation air methane use technologies, EPA has gathered cost data and prepared marginal abatement cost (MAC) analyses for the production of power using flow reversal reactors. This technology has successfully oxidized VAM and produced steam, and will shortly take the next step by generating electricity. Put simply, MACs estimate how much it costs to oxidize and produce power for a certain quantity of VAM. EPA chose flow reversal reaction as the mitigation technology for the development of MACs because it is close to commercialization, cost estimates are promising, and the technology can use the widest range of VAM concentrations.

As Table 1 shows, of the total of 237 million metric tons of CO_2e VAM emissions (16.6 billion cubic meters 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. Translating these costs to market size, at US$3.00/tonne CO_2e nearly 3,000 MW of net electric capacity could be developed, and annual power sales revenue could approach $900 million.

China, the world's largest emitter of methane from coal mining, has by far the greatest project opportunities and a total estimated equipment sales potential of over US$3.8 billion, with over 1,300 MW of new generation capacity and over US$430 million in annual power sales, assuming a CO_2 equivalent cost of US$3.00 NPV/tonne.

In the US, with power sales at US$0.03 per kWh and US$3.00/tonne CO_2 equivalent, a potential equipment sales market of almost US$1.5 billion exists to support development of

almost 550 MW of new power generation capacity and over US$140 million in annual power sales revenue.

Ukraine and Russia also offer significant opportunities with equipment sales potentials of over US$900 million and almost US$500 million, respectively. Australia and the United Kingdom, which have aggressive government programs to support electricity generation from renewable sources, also offer attractive opportunities. In addition, there are many viable projects in a number of other nations.

4.0 Conclusion

This paper demonstrates that there is a large global supply of ventilation air methane, which can become an energy and environmental resource because of the technologies that exist or are under development to harness this resource. In order to develop this vast market, however, a number of coordinated steps must be undertaken.

- The technologies require demonstration at commercial scale. Currently, demonstration efforts are planned or are already underway in both Australia and the U.S. Field demonstrations in other countries would be useful to better understand the practical issues involved in adapting the technologies to the national conditions and markets.

- Reasonable prices for both the extracted energy and greenhouse gas emission reductions are necessary. At prevailing power prices, over two thirds of global VAM could be mitigated for less than $3.00/tonne CO_2e.

- For those projects seeking revenues from the avoided emissions, accurate quantification of the emissions baseline, plus monitoring, verification, and third party certification, are important. Protocols developed by industry and other interested parties will expedite the process.

- All interconnections between the ventilation air evasé and the oxidation unit must be designed and, where required, approved to remove any safety concerns for mining operations. The experiences of demonstration project developers in Australia and the U.S. in obtaining safety approval will be useful in all gassy coal mining regions..

- Information on the VAM mitigation technologies, markets and other issues related to project development must be compiled, assessed and disseminated. EPA already has a web site (www.epa.gov/coalbed, visit the “ventilation air methane” section) that provides a significant amount of technical and market data, and EPA will continue its efforts to develop and provide unbiased information to industry and to partner with other organizations world wide.

Developing the global ventilation air methane resource is likely to be a challenge for all who take part in this important effort. However, the technical and market fundamentals are strong, and the demand for low cost, high-quality greenhouse gas emission reductions appears great, so relatively prompt deployment of these technologies is both possible and beneficial – economically and environmentally.

Nomenclature

Bm^3	Billion cubic meters
CBM	Coalbed methane
CMM	Coal mine methane
CMOP	Coalbed Methane Outreach Program
CO_2e	CO_2 equivalent
kWh	KiloWatt-hour
MAC	Marginal abatement cost
Mm^3	Million cubic meters
MW	MegaWatt (million Watts)
NPV	Net present value
EPA	United States Environmental Protection Agency
VAM	Ventilation air methane

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References

1. U.S. EPA, 2003, Assessment of the Worldwide Market Potential for Oxidizing Coal Mine Ventilation Air Methane, p. 7.
2. U.S. EPA, Technical and Economic Assessment: Mitigation of Methane Emissions from Coal Mine Ventilation Air, 2000

Tables and Figures

Table 1. Potential Worldwide Market for VAM Projects (@ under $3.00/tonne CO_2e)

Country	Total 2002 VAM Emissions (Bm^3)	Total 2002 VAM Emissions <$3.00 Tonne CO_2e (Bm^3/y)	Net Electric Capacity (MW)	Equipment Sales (US$000,000)	Annual Revenue (US$000)
China	6.7	5.48	1,367	3,811	431,321
U.S.	2.6	2.17	549	1455	148,412
Ukraine	2.2	1.13	263	910	71,383
Russia	0.7	0.61	141	498	56,002
Australia	0.7	0.37	96	243	17,310
Poland	0.4	0.26	52	258	22,364
Kazakhstan	0.3	0.04	11	29	1,726
Czech Republic	0.1	0.06	13	47	5,579
U.K.	0.2	0.14	33	104	8,986
Mexico	0.1	0.10	27	62	11,480
Germany	0.1	0.07	16	63	9,178
Study Country Totals	14.8	10.43	2,568	7,480	783,742
Other Countries	2.5	1.5	377	1,098	115,045
World Totals	**17.3**	**12.0**	**2,945**	**8,578**	**898,787**

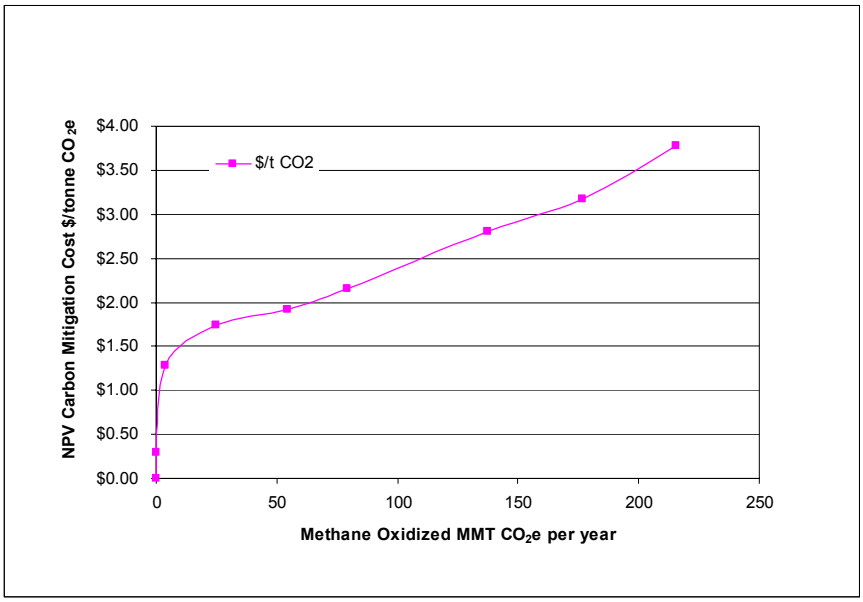

Figure 1. Global Marginal Abatement Cost Curve for Ventilation Air Methane Mitigation