

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. The U.S. Environmental Protection Agency (EPA) estimates that global ventilation air methane emissions in 2000 exceeded 17 billion cubic meters (600 billion cubic feet)—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 for heat and power, 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 summarizes research characterizing national ventilation air methane emissions and analyzes flow-reversal reaction's applicability to cost-effectively reduce ventilation air methane emissions. Based on market and cost analyses performed by EPA, at a marginal cost of US\$3.00 per tonne of CO₂ equivalent, 172 million tonnes of CO₂ equivalent ventilation air methane may be oxidized globally.

1. 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 1 percent methane concentration. Almost all of this ventilation air methane (VAM) vents to the atmosphere. EPA estimates that global VAM emissions in 2000 exceeded 17 billion cubic meters (600 billion cubic feet)—the equivalent of 237 million tonnes of carbon dioxide.

Eighty-eight percent of all VAM emissions are found in only 12 countries. China alone is responsible for over a third of all emissions, followed by the United States, Ukraine, Russia, and Australia. Methane concentrations vary from ventilation shaft to ventilation shaft and from country to country. In only a few cases did concentrations exceed 1.0 percent, but in most countries studied some proportion of mine shafts released ventilation air with over 0.5 percent methane.

EPA, other government and research organizations, and 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 is 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 to gain hands-on experience with projects that demonstrate the technologies.

This paper focuses 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. 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*^{1,2} 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 based on prevailing power prices and carbon dioxide-equivalent (CO₂e) emission reductions.

The report shows that 88 percent of all VAM emissions are found in only 12 countries. As Table 1 demonstrates, China alone is responsible for about 39 percent of all emissions. China's emissions combined with those of the United States, Ukraine, Russia, and Australia represent about 75 percent of total VAM emissions.

3. Global VAM Oxidation Market

To understand the size and scope of the global market for VAM use technologies, EPA 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 it will shortly take the next step and generate 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 237 million total tonnes of CO₂e VAM emissions (16.6 billion cubic meters of methane), with a net project cost of US\$3.00 per tonne of CO₂e and average industrial power prices, approximately 172 million tonnes of CO₂e could be oxidized. Translating these costs to market size, at US\$3.00 per tonne of CO₂e, nearly 3,000 MW of net electric capacity could be developed, and annual power sales revenue could approach US\$900 million.

As the world's largest emitter of methane from coal mining, China 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 CO₂e cost of US\$3.00 net present value per tonne.

In the US, with power sales at US\$0.03 per kWh and US\$3.00 per tonne of CO₂e, 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, both with aggressive government programs to support electricity generation from renewable sources, also offer attractive opportunities. In addition, there are many viable projects opportunities in other nations.

4. Conclusion

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. 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 United States. 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 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 US\$3.00 per tonne of CO₂e. As a point of comparison for that carbon emission unit price, projects that offer essentially no risk to the World Bank's Prototype Carbon Fund (through delivery assurances, etc.) now can secure an upper end purchase price of US\$4.20 per tonne of CO₂e.³
- For those projects seeking revenues from the avoided emissions, accurate quantification of the emissions baseline, 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 methane 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 United States in obtaining safety approvals 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 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 for industry and to partner with other organizations worldwide.

Developing the global VAM 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

| | |
|-------------------|--------------------------------------|
| CBM | coalbed methane |
| CMM | coal mine methane |
| CMOP | Coalbed Methane Outreach Program |
| CO ₂ e | carbon dioxide equivalent |
| KWH | kilowatt-hour |
| MAC | marginal abatement cost |
| Mm ³ | million cubic meters |
| MW | megawatt (million watts) |
| EPA | U.S. Environmental Protection Agency |
| VAM | ventilation air methane |

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End Notes

1. EPA, 2003, Assessment of the Worldwide Market Potential for Oxidizing Coal Mine Ventilation Air Methane, EPA-430-R-03-002, July 2003.
2. EPA, 2000, Technical and Economic Assessment: Mitigation of Methane Emissions from Coal Mine Ventilation Air, EPA-430-R-001, February 2000.
3. Phone discussion with Chandar Shekhar Sinha, Portfolio Manager for Carbon Finance, Prototype Carbon Fund, 15 August 2003.

Tables and Figures

Table 1. Potential Worldwide Market for VAM Projects (@ under \$3.00/tonne CO₂e)

| Country | Total 2002 VAM Emissions (Bm ³) | Total 2002 VAM Emissions <\$3.00 Tonne CO ₂ e (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

