A 2012 update on the world VAM oxidizer technology market

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ABSTRACT: Methane is a powerful greenhouse gas and the principal component of natural gas. Coal seams often contain significant quantities of methane, and underground coal mines must ensure that methane released into the mine during coal extraction does not build to dangerous levels. This is accomplished in part through the use of ventilation systems that remove methane from the mine and release it to the atmosphere. Although the methane concentration exhausted is quite low (typically ≤ 1 percent), the volume of air that ventilation systems move is so great that it actually constitutes the largest source of methane emissions from underground coal mines. Each year underground coal mines throughout the world emit more than 500 billion cubic feet of methane from their ventilation systems. Mines that choose to mitigate these emissions can often obtain carbon credits as an additional revenue stream.

Oxidation using a thermal flow-reversal reactor (TFRR) has emerged as a tested and commercially-available solution for VAM emission mitigation and TFRR projects have been built in the United Kingdom, Australia, China and the United States. In addition, a regenerative catalytic oxidizer is being constructed in China. If the technology is employed at active underground coal mines, it offers the potential to mitigate substantial quantities of global methane emissions. Oxidizers also have the ability to tap the excess heat to produce steam for electric power generation. This paper discusses global VAM emissions, technology options, the state of the market, and the factors which lead to successful VAM projects.

1 Introduction

Methane, a powerful greenhouse gas, is often found in coal seams. As a result, significant quantities of methane gas can be released into underground mine workings as part of coal mining operations. Because concentrations between 5 and 15 percent are explosive in air, mines must ensure that methane does not build to dangerous levels within the mine. This is accomplished in part through the use of large-volume ventilation air systems that dilute and remove methane from the mine. Although the concentration of exhausted methane in ventilation air is quite low (typically <1 percent), the volume of mine air that ventilation systems move is so great that they actually constitute the largest global source of methane emissions from underground coal mines. As shown in Table 1, five countries make up over 75 percent of ventilation air methane (VAM) emissions.[1]

The annual VAM emissions from these 5 countries is equivalent to almost 40% of global coal mine methane emissions (CMM). Having a global warming potential of 21 times greater than an equivalent weight of carbon dioxide (CO_2), global CMM emissions were estimated to be approximately 584 $MMTCO_2E$ in 2010, accounting for 8 percent of total global methane emissions.[2]

Table 1. Major sources of VAM emissions.

Country	2009 UG Coal Production (MMT)	2009 VAM Emissions (Bm^3)	2009 VAM Emissions ($MMcCO_2e$)
China	2663	18.2	259.1
United States	378	2.8	40.3
Ukraine	97	2.6	36.9
Australia	117	1.3	17.6
Russia	100	1.0	14.6
Total	3355	25.9	369

2 Development of VAM Oxidizer Technology

Several manufacturers began pilot scale demonstrations of technologies for the destruction of VAM in the 1990's. These VAM destruction technologies are based on the same technologies used for many years for the destruction of volatile organic carbon (VOC) emissions. The demonstrations were very successful and led to ten commercial scale projects coming on line between 2007 and 2012 in Australia, U.K., U.S. and China (see Figure 1 and Table 2). As a result of these projects, the technical and economic performance of the technologies is relatively well documented and the technical risk is considered relatively low.

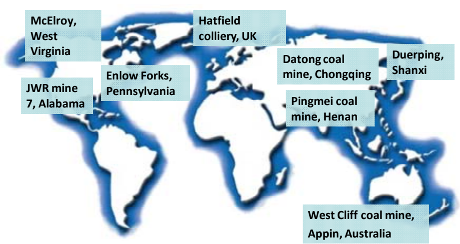

Figure 1. Worldwide VAM projects in 2012.

Predominantly, developers are offering technologies based on regenerative thermal oxidation (RTO). However, the Natural Resources unit at Duerping, China is a regenerative catalytic oxidizer (RCO). The West Cliff technology is also demonstrating the use of supplemental CMM to maintain sufficient heat output to generate electric power.

The units that have been operating for several years are demonstrating 95+% destruction efficiency of methane with a 90+% availability. Although RTO and RCO technologies will destroy methane at levels as low as 0.2 percent, the most ideal sites for these technologies are ones that have VAM concentrations ranging from 0.5 to 1.9 percent methane in ventilation flows of 100,000 standard cubic feet per minute (scfm), or more. Figure 2 presents the distribution of VAM concentrations in U.S. underground mines, as documented in a U.S. EPA study of 2008-2009 Mine Safety and Health Administration (MSHA) data.[3] As shown by the bar chart, at least 50 U.S. underground mine shafts have methane concentrations above 0.4 percent.

The developers offering VAM destruction technologies also offer a wide range of financial agreements, ranging from sale of a turn-key facility, to various lease agreements, to profit sharing, to simple royalty payments. Figure 3 presents the pro-forma for a 200,000 scfm RTO at two VAM concentrations.

Work continues on the development, demonstration and optimization of various VAM technologies. Four of these technologies are compared in Table 3. Figure 4 shows the RTO installation at the DaTong Coal Mine in the ChongQing Province, China.

Table 2. Summary of worldwide VAM projects in 2012.

Owner, Mine, Location, Developer	Oxidizer Supplier	VAM Flow Nm^3/hr	Start-up Yr
Consol Energy, Enlow Forks, Pennsylvania, USA, Consol, Green Holdings	Durr Systems, USA	480,000	2012
Consol Energy, McElroy, West Virginia, USA, Consol, Sindicatum Carbon Capital	Durr Systems, USA	510,000	2012
Sindicatum, Duerping, Shanxi, China, Sindicatum Carbon Capital	Sindicatum, Natural Resources, Canada	72,000	2012
Sindicatum, Duerping, Shanxi, China, Sindicatum Carbon Capital	MEGTEC	120,000	2012
Hatfield Colliery, Hatfield Colliery, UK, HEL-East, Ltd.	HEL-East, Ltd.	90,000	2011
SongZao Coal & Electricity, DaTong, Chongqing, China, AES Co., SongZao Coal & Electricity, Shenzhen Dongjiang Environmental Renewable Energy	MEGTEC	375,000	2011
Pingdingshan Coal Group, Mine 4, Henan, Shengdong	Shengdong		2010
Jim Walter Resources, Mine, Alabama, USA, Biothermica Technologies	Biothermica Canada	50,000	2009
ZhengZhou, GaoCheng, Henan,China, EcoCarbone	MEGTEC	60,000	2008
BHP-Billiton, West Cliff, New South Wales, Australia, BHP-Billiton	MEGTEC	250,000	2007

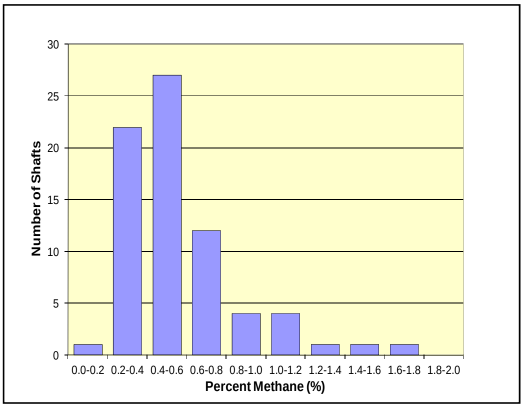

Figure 2. Distribution of VAM concentrations in U.S. underground mines.

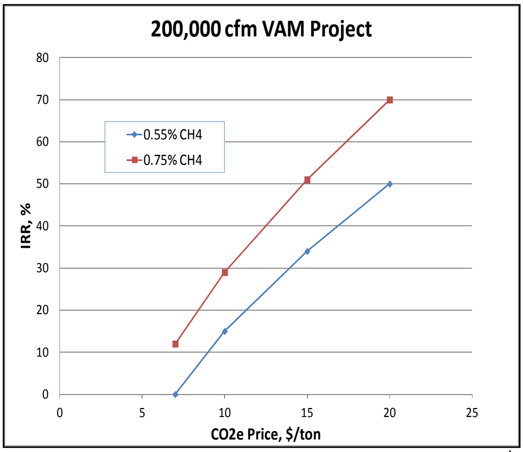

Figure 3. Internal Rate of Return for 200,000 scfm RTO.[4]

Figure 4. RTO installation at the DaTong coal mine in the ChongQing Province, China, (Photo courtesy of MEGTEC)

Table 3. Comparison of four VAM mitigation technologies.

Single Can RTO w/ Ceramic Media	Two Can RTO w/Ceramic Media	Two Can RCO w/ Catalytic Media	Combustion Air for Power Turbines
Technology: Advantage			
Proven Technology, most experience. Compact design. Embedded steam pipes enable heat recovery if concentration permits.	Mature, proven technology. Longer residence time, lower oxidation temperature and parasitic load. A range of suppliers to choose from.	Reduced oxidation temperature and parasitic load. Longer residence time, higher thermal efficiency. Mechanical design is proven.	Additional energy content of VAM reduces overall fuel use.
Technology: Disadvantage			
Low residence time, higher oxidation temperatures and parasitic load. High equipment cost.	Larger footprint than single can design.	Catalytic media can be poisoned by contaminants in the VAM. Catalyst unproven. High equipment cost, high technical risk.	Dirt/water in VAM causes significant operational difficulties. New and unproven technology. Only consumes a small volume of VAM.

3 Market Opportunities for VAM Oxidizers

The key factor limiting more wide spread application of VAM destruction technology is the lack of economic market or regulatory drivers for VAM destruction. The primary drivers for the current VAM projects have been the carbon markets for the reduction of greenhouse gas (GHG) emissions under the United Nations Framework Convention on Climate Change (UNFCCC) and other voluntary initiatives. The Kyoto Protocol, created and adopted under the UNFCCC, is an international regulatory framework that defines clear emission reduction commitments using flexible mechanisms (i.e., Clean Development Mechanism (CDM), Joint Implementation (JI)) that have laid the foundation for the development of the international carbon market. In addition to CDM and JI, a voluntary carbon market was established primarily by companies and individuals that purchase emission reductions to offset their carbon footprint. Currently, both the CDM and JI carbon markets are driven by commitments under the Kyoto Protocol which are undefined after expiration of the protocol at the end of 2012. Just recently the international community agreed to the "Durban Platform" which commits to extend and expand the Kyoto Protocols for several more years. However, the details of the Durban Platform are yet to be developed or adopted. This uncertainty in the future UNFCCC program results in a soft compliance carbon market and creates financial hurdles that reduce investment opportunities. In addition, as a result of the global economic recession, the current monetary value and interest in purchasing voluntary carbon reductions is very low, which also limits investment in VAM destruction.

Table 4 summarizes the world market opportunities for VAM destruction technologies. Although the current market for VAM destruction is soft, when carbon prices were as high as \$20/tonne (before 2008), the annual 300 MMTCO$_2$E of VAM emissions represented a potential annual market of \$6 billion. But in recent years, carbon prices have declined and become subject to increased volatility. Several factors could reduce the economic risk of investing in VAM technologies and improve the VAM destruction market. A firm commitment by the international community to an extension of the Kyoto Protocols for many more years or some other form of regulatory mechanism would send a clear market signal and revive the price of carbon reductions for signatory countries. As an alternative, countries can take unilateral measures like China, which has extended the value of carbon reductions implemented in China by offering letters of approval (LOA) under the CDM that honor the sale of carbon reductions through 2020. Australia has recently adopted a carbon tax on significant GHG sources that could create a market for VAM destruction at gassier mines. Currently the European Union does not include methane or methane reductions in countries within its mandatory GHG reduction program. Broadening the European Union GHG trading program (EU ETS) to include methane would greatly expand the VAM market to European mines. Countries and organizations can also provide incentives for VAM destruction. Grants such as those provided by Australia, Quebec and the U.S. greatly facilitated the BHP West VAMP, J.R. Walters Black Warrior and Consol Windsor projects respectively.

Table 4. World market opportunities for VAM technologies.

Country, 2009 Coal Production (10^6 MT/yr)	VAM Output 10^9 m^3	Mining Conditions	Market Comments
China 2,666	18.3	Numerous underground coal mines are very gassy.	CDM mechanism in place with carbon value extended until 2020 to enable return on investment.
India 529		Most underground mines are small scale and not gassy, currently offering poor conditions for VAM abatement.	Coal India plans to dramatically increase coal production by 2020.
United States 378	2.8	Large gassy mines give favourable conditions for VAM abatement projects.	Weakened global voluntary carbon market (VCM) presents high financial risk hurdles.
Russia, Ukraine, Kazakhstan 300[a]	6.2[a]	Wide range of mining techniques, mining conditions and levels of mechanisation.	Significant potential for VAM abatement projects.
South Africa 250		Mines tend to be shallow, thus not gassy.	Good future potential as coal mines access deeper reserves.
Australia 117	1.3	A number of gassy underground mines are in operation.	Recent adoption of carbon tax could provide a mechanism for return on investment.
Mexico 12		Majority of mines use modern longwall techniques and exhibit favorable VAM abatement characteristics such as large volumes and high VAM concentrations.	CDM and VCM mechanisms in place with carbon value till 2020 to enable return on investment.

[a] Combined values for 3 countries.

For more information on VAM technologies and potential opportunities, please visit the U.S. EPA Coal Bed Methane Outreach Program (CMOP) website: http://www.epa.gov/cmop/resources/vam.html. The authors gratefully acknowledge the contributions of time and information cited in this article from Neil Butler, HEL-East Ltd., Retford, UK, Nicolas Duplessis, Biothermica Technologies, Montreal, Canada and Richard Mattus, MEGTEC Systems, USA.

4 Summary and Conclusion

Coal mine ventilation air is a large global source of methane emissions from mining activities, and the destruction of this methane offers a very significant greenhouse gas mitigation opportunity. Oxidation technology for the destruction of VAM has matured through the success of multiple long term full scale demonstration and commercial projects implemented across several continents. Based on the estimated quantity of VAM emissions, the world market for VAM destruction technologies has a potential value of several billion dollars. However, as the world's focus temporarily slips away from climate change to international financial stability, the lack of medium term clarity for the carbon market means that these technologies are not being implemented as quickly as the opportunity deserves. In response, there are several measures that governments and organizations can take to boost the VAM destruction market, including financial incentives, and regulatory and market based programs.

5 References

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