Case study: CMM utilisation and methane emissions mitigation at three large coal mines – China

Initial conditions: Three large mines with a combined coal production capacity of 14 Mtpa located close to Taiyuan, the provincial capital of Shanxi Province, China, were capturing a total of around 140 m^3/min methane which was being vented to the atmosphere. There was scope for further increasing CMM capture at the mines. National, provincial and company policy was to seek a means to harness CMM to produce clean energy and to mitigate greenhouse gas emissions. High and rising power prices provided a major incentive for coal mines to generate electricity for self-use.

Utilisation and mitigation problems: The mines wished to install modern gas-engine technology and maximise power generation yet they had no experience of CMM utilisation. There was a corporate desire to identify and implement best practice gas extraction, use and mitigation employing imported technology. However, difficulties were envisaged with financing, operating and maintaining foreign equipment. Too often in the past technology had been imported into China which fell into decay through lack of operational expertise and failure to invest in preventive maintenance. There were also issues of variable methane concentration and flows at the mines to resolve.

All the project sites were located in mountainous areas, the highest at an altitude of 1600 m, and subject to weather extremes with snow in winter and high midday temperatures in summer. Construction could therefore not be carried out safely or effectively in winter and operational equipment would need to function reliably under a wide range of climatic conditions.

Solution:

Project construction. A major State-owned coal mining company and its operating subsidiary partnered with an international project developer to build and operate CMM co-generation projects at three gassy coal mines. The projects were to be CDM registered under the UNFCCC. The international partner financed all the equipment while the Chinese mining partner provided land and financed the design and civil works. Each project required the preparation and government approval of a feasibility study prior to final design and implementation. Government regulations in China restrict design activities to specialist, certified institutes. The project developer's engineering team worked with the Chinese design institutes to help them understand the new technologies being introduced and also to encourage adoption of western standards, especially with regard to health and safety. Environmental impact assessments were prepared, reviewed and officially approved prior to construction.

After approval, a public bidding process for supply and installation of the project equipment under an Engineering Procurement Construction (EPC) type contract was initiated. Technical detail was then discussed with the preferred bidder and final terms agreed. Due to severe winter conditions, construction was only feasible for 8 to 9 months of the year. The implementation schedule is summarised in Table 1.

The platforms for the CMM project sites were formed by cut and fill in hilly terrain with poor soil conditions. Engines were accommodated in containers which prevent noise pollution and the engine combustion emission controls meet the latest standards.

Table 1. Implementation schedule

Activity	Mine D	Mine T	Mine M
Co-operation agreement between partners signed	August 2007	March 2008	March 2008
Site preparation started	June 2007	June 2009	March 2009
Phase 1 power generation commenced	May 2008	June 2011	August 2010
Phase 2 power generation commenced	November 2010	Expected September 2016	November 2014

The CMM co-generation project at coal mine T suffered serious delays due to landownership issues compounded by a serious underground explosion in February 2009 which fully occupied both mine and group management for a substantial period of time. Later, a protracted engine warranty dispute meant the full capacity of the plant was not realised for almost two years after completion. The local designers included a large gas-holder to buffer CMM supply but due to a regulatory issue it remains unused but there has been no measurable impact on project performance.

Initial performance of the power plant at mine M was lower than planned due to insufficient capacity of the gas cooling system which was subsequently rectified.

All three projects were successfully registered as CDM projects under the UNFCCC and avoid in total over 1 million tonnes carbon dioxide equivalent annually. Emission verifications have been completed successfully at all the sites and will continue for the 10-year life of the projects. Over 30 MWe of electrical generation capacity has been installed and further expansion of project T is being considered. Some 65 new jobs have been created in poor mining areas to the benefit of local economies together with improvements in local infrastructure.

Engineering issues and solutions. Technology transfer was an essential component. Investment and technical assistance was provided by an international project developer with an experienced mining and engineering team. Nevertheless, there was some resistance to new ideas especially where there was conflict with existing, but often outdated, design practices and rules.

The power plants were constructed in phases to build experience in operation of sophisticated foreign gas-engines and to allow time for improvements in gas capture and quality at the mines (Figures 1 and 2). Training was given by the technology providers and technical support services were available from the project developer's office in Taiyuan within short driving distance of all the sites. Additionally, a proprietary remote monitoring system was developed to facilitate a rapid response to fault warnings and optimisation of emission reductions.

Suitable protection against climate extremes was devised to ensure that pre-treatment systems, engines, monitoring and control systems function under all weather conditions. Nevertheless, the challenging conditions during summer and winter periods can limit gas-engine loads and increases the maintenance downtime periods.

The international mining team worked with the project mines to raise gas management standards and to ensure methane concentrations consistently above 30% for safe gas capture, transport and utilisation. In the absence of a national Chinese standard, the international team developed an operational guidance document for the surface CMM plants. Principal improvements at the mines resulted from attention to drainage borehole drilling and regulation, introduction of new methods for dewatering gas drainage pipelines and enhanced suction pressure control at the surface extraction stations.

The overall performance of the projects is summarised in Table 2. A target power generation availability of 80% has not been achieved due to factors relating to plant operations, maintenance and CMM supply. CMM gas flow varies with coal production rate and is affected by longwall stoppages due to geological problems, underground longwall face changeovers and mine maintenance activities. Power plant availability is calculated by multiplying the percent of engine running time by the percent of engine load achieved.

CMM projects at the three mines continue to operate as designed despite poor returns from the certified emissions reductions and consistently achieve emission mitigation targets because excess gas from power generation, especially during downtime periods, is destroyed in the flares.

There is potential to improve power generation at the case study sites by further enhancing operational and maintenance practices – spares availability, preventive maintenance and advanced training for technical staff. Heat recovery systems are only used in the winter (approximately 5 months) for shaft heating at mine D and hot water and space heating at the other sites. All-year round uses for waste heat which are commercially viable have not been identified.

Table 2. Summary of CMM project performance

CMM project coal mine	CDM project UNFCCC registered	Power generation capacity MWe (2015)	Flare capacity m^3/h	Typical annual power export MWh	Cumulative power export to 31 July 2015 MWh	Typical emission reduction tCO_2/year	Overall power plant generators availability	Overall availability of flares
Mine D	9 March 2009	11.9	1 x 5,000	69,300	380,200	385,000	66%	20%
Mine T	17 Dec 2010	12.2	4 x 2,000	62,000	266,900	482,000	59%	90%
Mine M	3 Dec 2010	7.5	2 x 1,500	24,700 Phase 1 only	120,400	192,800	75%	80%

Lessons: This case study shows how modern CMM–fuelled power generation, heat recovery systems and flaring units can be integrated into a system in which virtually all of the drained gas can be used or destroyed - a key step towards near zero emissions mining. The benefits to coal mines are power savings and substitution of clean energy from waste heat recovery for water, space and shaft heating previously provided by polluting coal burning boilers.

High power prices alone may not be sufficient to encourage investment in state-of-the-art CMM utilisation. Carbon financing linked with technology transfer was demonstrated to be an effective driver in this case study.

The amount of time required to obtain necessary consents and approvals for a CMM project should not be under-estimated. Project timing and schedules must take account of the impracticality and hazards of working in extreme winter conditions. Equipment and installations must also be designed to operate satisfactorily in all weather conditions likely to be encountered.

Mines introducing technologies with which they are not familiar with must have ready access to technical support and specialist services in the locality of the project sites. Equipment performance depends not only on its initial specification and installation but also on how it is operated and maintained.

Figure 1. CMM co-generation power plant phase 1 at mine D

Figure 2. Flare system at mine T