Coal Mine Methane in China: A Budding Asset with the Potential to Bloom

An Assessment of Technology, Policy and Financial Issues Relating to CMM in China, Based on Interviews Conducted at Coal Mines in Guizhou and Sichuan Provinces

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Table of contents

Introduction

Executive Summary

The IEA is undertaking a strategic initiative to improve global analysis and understanding of energy sector methane emissions and recovery opportunities. This is one of a series of International Energy Agency (IEA) Information Papers designed to highlight specific opportunities for cost-effective reductions from oil and natural gas facilities, coal mines and landfills, with the aim of increasing methane recovery and utilisation globally.

The purpose of this paper is to identify and examine policies, technologies and practices in China for coal mine methane (CMM)[1] recovery and use, focusing on the unique challenges and opportunities of medium- and smaller-sized coal mines. Research for this report was conducted through a series of meetings and interviews with coal mine stakeholders in China, including national and provincial authorities, local officials, coal mining companies, financiers, international experts, and on-site interviews and visits to a number of coal mines in Guizhou and Sichuan Provinces conducted in 2008. These provinces are not the highest-capacity coal mining regions, but, like many other regions in China, they have strong coal resources and related potential for greater recovery and use of CMM. From this anecdotal information, the IEA is able to refer to broader trends about CMM in China and make policy recommendations. This report can be used by energy, environment, coal mining and climate change experts and policy makers in China and internationally to better understand the context, situation and opportunities for future development.

Coal mine methane recovery and utilisation began in China in the early 1990s as a strategy to enhance coal mine safety, diversify energy resources and make use of a fuel that had been previously wasted. This was followed by the recognition of the greenhouse gas (GHG) mitigation potential of CMM recovery and use, as the government enacted a series of economic and administrative policies designed to encourage CMM utilisation.

The most common project type is CMM power generation. There are many other uses in China, including town gas and vehicle fuel. Coal mines are also working to expand their CMM utilisation technology applications to make beneficial use of lower-quality CMM (i.e., below 30% methane concentration) as well as oxidising the very dilute (typically about 1% methane) ventilation air methane for power and/or heat generation. Demonstration projects have been developed to test these emerging technologies and the results are promising. Today, China has a number of large commercial projects in operation, including some funded under the Clean Development Mechanism (CDM) of the Kyoto Protocol, and more are planned.

However, despite this substantial progress, there is much additional potential in China for CMM recovery and use. The IEA identified a number of barriers to CMM recovery and utilisation in China, including: a lack of information and expertise at the local level about CMM power generation; ineffective subsidies for CMM electricity generation; a lack of degasification technologies suitable for the Chinese coal seams; a lack of markets to use the recovered methane; and challenges in utilising the CDM to finance CMM projects.

1. Coal mine methane should be distinguished from coal bed methane (CBM): coal mine methane is the gas that is released immediately prior to, during, or subsequent to coal mining activities and, thus, has climate change impacts; CBM is exploited as a natural gas resource. For a glossary of international terms related to CMM, see http://www.unece.org/energy/se/cmm.html.

To address these barriers, this report recommends that the national government prioritise CMM recovery and utilisation by improved implementation of policies, particularly at the provincial level. Some suggested next steps include improving capacity of provincial and local government authorities to deal with CMM issues; more active engagement of key stakeholders like the China State Power Network Group Corporation in CMM subsidy development; improving the capacity at smaller coal mines for CMM recovery and utilisation; and providing incentives to qualified engineers and skilled workers to run CMM recovery and utilisation projects in coal mines, particularly in smaller mines.

If China is able to address these barriers, the promising CMM industry that has been strongly established in some key provinces of China (for example, Shanxi Province) – but is only now beginning to develop at medium- and smaller-scale mines in Sichuan, Guizhou and elsewhere – could come into full bloom, leading to a number of energy supply, local employment and global environmental benefits.

Background

Energy and Climate Change Context

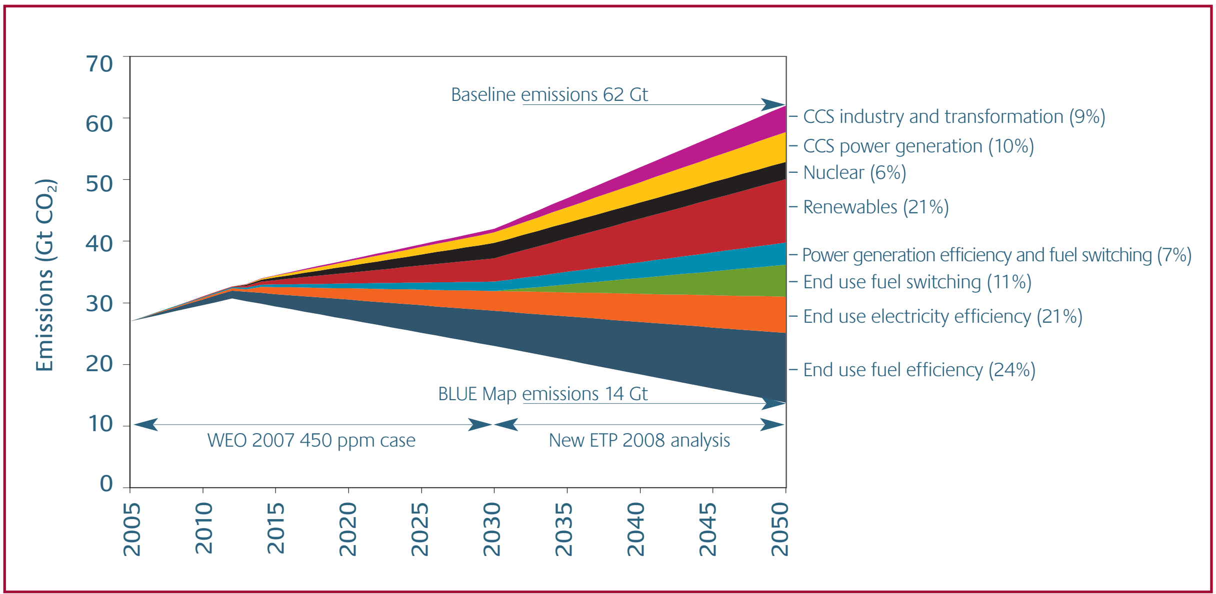
Rising carbon dioxide (CO_2), methane (CH4), and other GHG concentrations in the atmosphere, resulting largely from fossil-energy production and combustion, are contributing to higher global temperatures and to changes in the climate. According to the best estimates of the Intergovernmental Panel on Climate Change (IPCC), a stabilisation of long-term CO_2-equivalent concentration in the atmosphere at about 550 parts per million (ppm) would correspond to an increase in average temperature of around 3°C above pre-industrial levels. In order to limit the average increase in global temperatures to a maximum of 2.4°C, the smallest increase in any of the IPCC scenarios, the atmospheric GHG concentration will need to be stabilised at 450 ppm.

According to the IEA's Energy Technology Perspectives analysis (IEA, 2008), to achieve global climate stabilisation by 2050 will require rapid adoption of all energy efficiency, low carbon or zero carbon technologies (Figure 1). Methane recovery and use technologies are a particularly interesting part of this portfolio, as they are low-cost (or profitable) emissions reduction activities that reduce GHG concentrations in the near-term, essentially giving the other technologies time to develop and reduce their costs.[2]

2. The atmospheric lifetime of methane is 12 to 15 years. Therefore, emissions reductions realised today will have an impact on GHG concentrations within 12 to 15 years; compared to 100 to 200 years for CO_2. For more information on global warming potential (GWPs), see the IPCC *Third Assessment Report: Climate Change 2001* at http://www.grida.no/publications/other/ipcc_tar/?src=/climate/ipcc_tar/wg1/247.htm.

Without further policies, China's primary energy demand is projected to more than double from over 1 700 million tons of oil equivalent (Mtoe) in 2005 to over 3 800 Mtoe in 2030, an average annual rate of growth of 3.2% (IEA, 2007). Coal has been the primary energy solution for China, and the government has taken a number of steps since the mid-1990s to expand coal output. Successive Five-Year Plans and recent energy and environmental policies provide the framework for sustainable development. The 11th Five-Year Plan (2006 to 2010) sets a target to reduce energy use per unit of GDP by 20% by 2010 compared to 2005 and calls for a 10% reduction in key pollutant emissions. The government is promoting vigorous development of renewables, natural gas and nuclear power and, in June 2007, China unveiled its National Action Plan on Climate Change, which includes goals to develop clean coal technologies, but does not specifically mention CMM utilisation.

FIGURE 1: AN ENERGY TECHNOLOGY PORTFOLIO IS NEEDED TO ADDRESS CLIMATE CHANGE



Source: IEA, 2008.

China's Coal Use and Related Methane Emissions

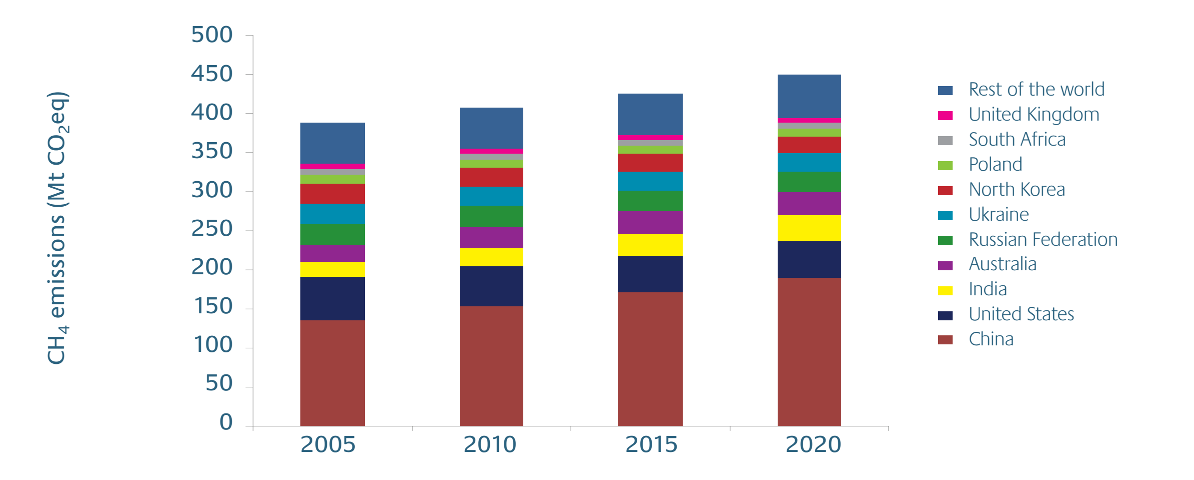
According to the government's figures, coal demand in China in 2010 will be over 3 billion tonnes (t) per year. To meet this demand, China is rapidly developing new coal mines. The country had a production capacity of 2.5 billion t in 2008; production capacity of an additional 1.1 billion t is under construction. Taking into account the retirement of old coal mines by 2010, China is expected to have coal production capacity of 3.1 billion t.[3]

3. IEA interviews with the China Coal Association and the National Development Reform Commission, Beijing China (September 2008).

Historically, coal supply in China came from publicly-owned mines of many types. However, over the past two decades, the government has implemented a policy to encourage diversification in coal mine ownership, increased efficiency and improved safety. As a result, today, coal is supplied by a variety of sources, including small, local and state-owned mines, private mines and larger state-owned mines. Illegal coal mining at smaller operations is also a concern. To address this, the government has closed tens of thousands of illegal mining operations. Today, China has between 10 to 15 000 coal mines operating, down from nearly 100 000 mines in the mid-1990s.

As a result of its coal production, China is the world's leading emitter of coal mine methane. In 2005, China's CMM methane emissions were over 135 million tonnes of CO_2 equivalent, over 40% of the world's total (US EPA, 2006); emissions are expected to increase in the future in tandem with increasing coal production. Figure 2 shows the largest CMM emitters by country.

FIGURE 2: GLOBAL METHANE EMISSIONS FROM COAL MINES



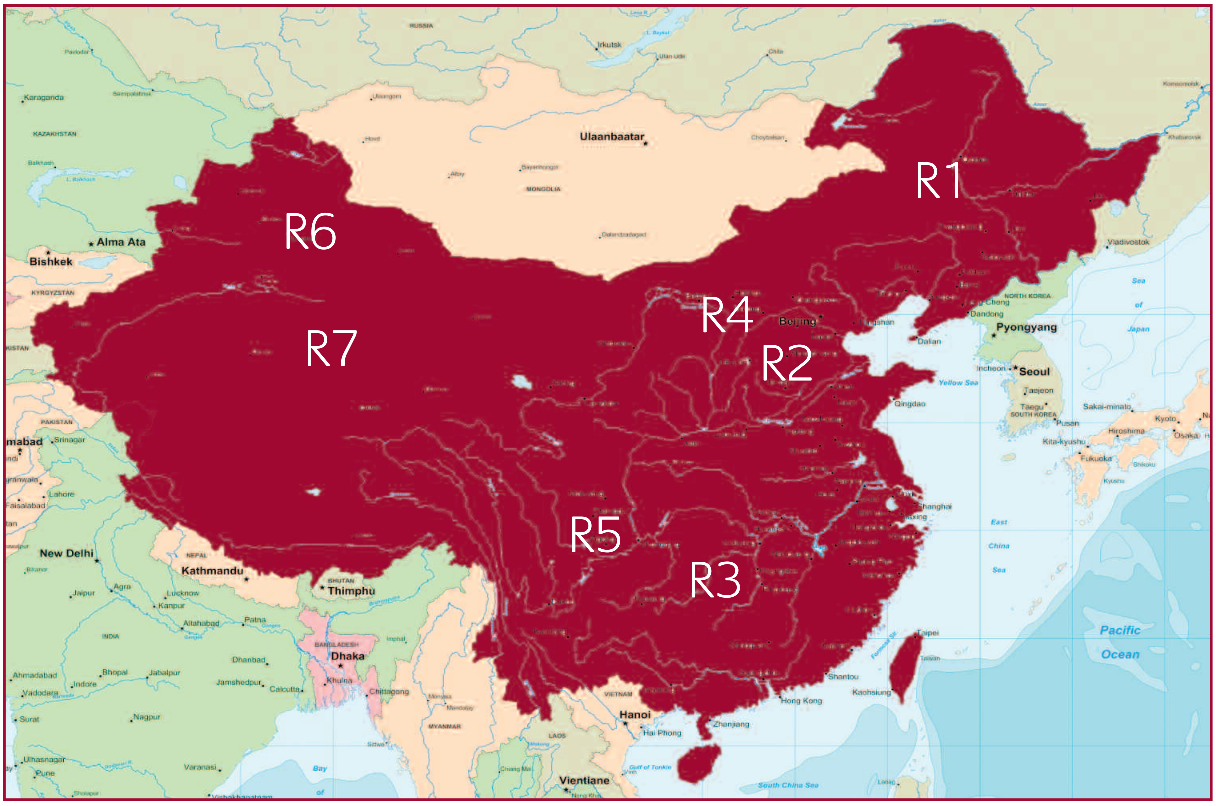
Source: US EPA, 2006.

China is rich in coal-related methane resources.[4] According to the latest evaluation on coal and coal mine methane by the National Development and Reform Commission (NDRC) and the Ministry of Land and Resources, coal-related methane resources buried to a depth of 2 000 meters (m) are over 34 trillion cubic meters (m^3), 12.5% of the world's total, ranking the third in the world (China University of Petroleum, 2008).[5] It is estimated that this amount of resources can be developed and utilised using current technology for the next 20 years. China has put a priority on developing coal-related methane resources at a depth of 300 to 1 500 m in the near future. China's coal-related methane resources can be divided into seven different geographic regions. Different regions have different kinds of coal resources and different concentrations of methane. Figure 3 shows the regional breakdown of these resources.

4. In China, official publications and statistics often combine CBM and CMM, making it difficult to distinguish CMM-only data. The numbers in this section (and the regional discussion below) refer to combined CBM and CMM resources.
5. China Energy and Environment Programme, *Feasibility Study of Coal-bed Methane Production in China*, EU (Europe Aid/120723/D/SV/CN), March 2008.

The government and industry are beginning to see CMM as a valuable resource which can be used as a feedstock for industrial chemicals and clean energy for power and heat generation. Like many countries, China has opportunities for greater recovery and use[6] of CMM. China imports natural gas from Australia and Central Asian countries. At the same time, China is venting billions of cubic meters of methane from coal mines into the atmosphere. Thus, CMM recovery and utilisation has recently become an important topic in China in terms of not only safety but also resource conservation, environmental protection and energy supply.

FIGURE 3: CHINA'S COAL-RELATED METHANE RESOURCES BY GEOGRAPHIC REGION



Source: China Energy and Environment Programme, Feasibility Study of Coal-bed Methane Production in China, EU (Europe Aid/120723/D/SV/CN), March 2008.

North-East China Region (R1)

The North-East Region consists of three provinces: Heilongjiang, Jilin and Liaoning. The coal strata in this region are located primarily in Cretaceous and Tertiary formations and Carboniferous-Permian formations. The Early Cretaceous coal basins are well developed and can bear high concentrations of methane. In the Tertiary formations, only the Fushun Basin in this region has higher-rank coals with high gas content; other basins in this region contain coal with low methane content. The coal beds formed in Carboniferous-Permian formations exist only in the southern part of the region. The thickness of coal seams in these coal beds does not change significantly, and they have higher methane contents. The methane resources are distributed mainly in Heilongjiang Province and Liaoning Province. In these two provinces, there are some rich methane belts such as Sanjiang-Mulinghe belt, Hunjiang-Liaoyang belt and West Liaoning belt.

6. Note that capture and flaring of CMM is also a viable GHG mitigation option, albeit one without additional energy benefit. As such, this option is not explored in detail in this paper.

North China Region (R2)

The North China Region covers provinces of Hebei, Shangdong, Henan and Anhui. It is located on the east side of Taihang Mountain, ranging from the Qinling tectonic belt in the west, to the Jiaolu fault belt in the east, from the southern boundary of Liaoning-Jilin-Heilongjiang region in North-East China, to the east section of Qinling-Dabieshan belt in the south. Coal strata are mainly Carboniferous-Permian formations, with some resources in Middle-Lower Jurassic Petroleum formations. The coal strata in the Carboniferous-Permian formations in this region are spread widely over a large sedimentation area, with stable coal seams and good gas content. As there are many districts with favourable exploration and exploitation prospects, methane recovery activities are very active in this region, and some outstanding progress has been achieved in Kailuan, Dacheng, Huaibei and Huainan coal mines.

South China Region (R3)

The South China region is located in the vast land ranging from Qinling-Dabieshan in the north and from Wuling Mountain in the west, including most of South-East and South China. Coal strata in this region are mainly in the Late Permian formations. A few of the Late Permian coal fields are preserved well, with relatively stable coal seams and good methane-bearing properties. The methane resources in this region are concentrated mainly in Jiangxi Province and Hunan Province, with abundant methane resources especially in Pingle and Xiangzhong belts.

Shanxi-Shaanxi-Inner Mongolia Region (R4)

Shanxi-Shaanxi-Inner Mongolia region is one of the richest coal mine methane resource areas in China. It is located in the west side of Taihang Mountain in the North China area, ranging from the Helanshan-LiuPansan fault in the west to the west boundary of Hebei-Shandong-Henan-Anhui region in the east, and including the west section of the Yinshan-Yanshan fold in the north and the west section of Qinling-Dabieshan fold in the south. Coal strata in this region are mainly in Carboniferous Permian and Middle-Lower Jurassic formations, with good gas content. In terms of methane content, the Qinshui and Hosie belts are the best, with the Shanbei and Huanglong belts relatively poor in gas availability.

South-West China Region (R5)

South-West China region consists of provinces of Yunnan, Guizhou, Sichuan and Chongqing. It ranges from the Longmenshan-Yanlaoshan fault in the west, to the west boundary of the South China coal methane region in the east, from the south boundary of Shanxi-Shaanxi-Inner Mongolia methane region in the north, to the country's boundary in the south. Coal strata in this region are located mainly in Permo-Carboniferous formations, with wide sedimentation area, stable coal seams, and high potential gas content. In particular, the Liupanshui belt contains the richest methane resources in this region. The Huayingshan belt, Yongrong belt, Chuannan-Qianbei belt and Guiyang belt are also rich in methane resources. Few methane resources have been found in Yale belt and Dukou-Chuxing belt. The Panzhhua area's Baoding coal mines are rich in methane, but the total amount is small and the thickness of coal seams changes significantly.

Coal mine methane recovery and utilisation projects in this area are developing very quickly. By the end of 2007, many coal mines – including Lubanshan Coal Mines in Sichuan Province, Liupanshui Coal Mine in Guizhou Province and Shongzao Coal Mine in Chongqing city area – have developed methane drainage systems and CMM power generation facilities.

North Xinjiang Region (R6)

The North Xinjinag region is located in Tianshan fold and the area north. In this region, there are many middle Jurassic coal basins such as Junggar, Turpan-Hami and Yili. Coal seams in this area are stable and thick, with good coal-bearing property. However, the coal grade is low (mostly long flame coal), and methane resources are relatively poor.

South Xinjiang-Gansu-Qinghai Region (R7)

Southern Xinjiang-Gansu-Qinghai region is located in the area at the south side of Tianshan, in the north-west coal accumulated area. It ranges from the west section of the Tianshan–Yinshan fold in the north, to the west section of Kunlun-Qinling fold in the south, from China's boundary in the west, to the west boundary of Shanxi-Shaanxi-Inner Mongolia coal methane region in the east. There are developed Middle Jurassic and Carboniferous-Permian coal basins in this region. The early to middle Jurassic coal seams here are low in coal grade, mostly canal coal, with poor methane-bearing property. The Carboniferous-Permian coal seams in this region are higher in coal grade, with limitation in distribution. This region lacks significant methane resources.

FIGURE 4: SHENGLI ENGINES AND GAS STORAGE TANK AT TIANFU COAL MINE IN SHAANXI, CHINA

Source: Raven Ridge Resources and Ruby Canyon Engineering

CMM Recovery and Use in China

History

In China, coal mine methane is considered first and foremost as a safety issue, as it has resulted in numerous accidents in China's mining history. CMM is one of several risks that threaten mine worker safety, including flooding, coal dust, fires and explosions. The equipment at many state-owned coal mines is outdated, creating safety risks. Most small mines still use primitive mining methods, and as a result are responsible for the great majority of coal mining fatalities. To address this risk, the government has put in place a number of policies requiring CMM drainage and use (see pp.13 to15 below).

According to industry observers, CMM development in China can be divided into four distinct phases (Pilcher, 2008). In the first phase, pre-1990, the Chinese government (the former Ministry of Coal Industry) and coal mine owners and operators were very focused on coal mine safety and on removing methane from the coal mines. The emphasis was not on capturing the methane and, therefore, very few CMM recovery and use projects were carried out. To address safety issues, China carried out underground gas drainage trials at coal mines in Fushun, Yangquan, Tianfu and Beipiao, when annual drainage was about 60 million cubic meters. Although CMM recovery and utilisation began to grow rapidly in developed countries during the 1990s, there was the perception that the geological and mining conditions in China were different from the West and, therefore, CMM recovery and utilisation experiences were not applicable to China. As a result, CMM that was captured in China was almost universally vented, and only a small portion was used for heating and cooking, mostly on-site at mines. There were a few attempts to use CMM for power generation using imported equipment but they were largely unsuccessful due to lack of servicing and adaptation to local conditions.

This situation began to change as China began CMM recovery and utilisation from 1991-96. During this period, the US Environmental Protection Agency (US EPA), the United Nations Development Programme (UNDP), and the World Bank's Global Environment Facility (GEF) developed targeted coal mine methane recovery and utilisation outreach efforts toward China. These efforts provided technical resources, financial support and information exchange to the Chinese government and other coal industry stakeholders. The first CMM surface pre-drainage and underground directional drilling demonstration project was financed by the UNDP/GEF and hosted by Kailuan, Songzao and Tiefa coal mines (Pilcher, 2008). The Chinese mine operators imported technologies and equipment for coal mine methane monitoring and testing and began to collect data. During this period, there were no major national government policies to facilitate CMM capture and use.

The third period, 1996-2004, laid the foundations for the current growth period for coal mine methane recovery and utilisation. A number of significant changes occurred during this time. First, the national government switched its policy focus from methane venting for mining safety to the encouragement of CMM recovery as a clean energy resource. Second, developed countries began to demonstrate consistent positive results with a number of CMM recovery and use technologies. Third, the Chinese government published CMM production forecasts. Fourth, large coal mines expanded their CMM resource development activities, although progress was slow and somewhat dependent on outside interest and investment. Fifth, the Asia-Pacific Economic Cooperation (APEC) funded a successful (and visible) CMM demonstration project at Tiefa Coal Mine in Liaoning Province that provided methane to the city's town gas supply network. Finally, the achievement of GHG emission reductions through the Kyoto Protocol's Clean Development Mechanism (CDM) became a new source of funding for CMM projects.

Selected CMM Projects in China

China's first CMM use project was at Liuzhi Coal Mine in Guizhou Province in 1991, and included two previously used 400-kilowatt (kW) gas turbines disassembled from an airplane generating electric power (Jiang, 2007). Seven years later, Huainan Coal Mine Group of Anhui Province began to install internal combustion engines for CMM power generation. By the end of 2006, the Group's installed power generation capacity totalled 32 megawatts (MW). Songzao Coal Mine and Power Company Ltd. in Chongqing city has also been developing CMM power generation projects since 2003. By the end of 2006, the company used 22 million cubic meters (M m^3) of CMM to generate nearly 51 gigawatt hours (GWh) of electricity.

In 2006, Lubanshan North Coal Mine and Lubanshan South Coal Mine of Sichuan Province Chuannan Coal Mine Company Ltd. started building CMM drainage systems and power generation units. About one year later, 7 MW of power generation capacity was in operation at the two coal mines. By February 2008, the capacity of two nearby coal mines reached a total of 8 MW, with 4 MW installed at each of the coal mines. These two power plants can burn almost 70 000 m^3 of methane, generating 170 MWh of electricity, and generating revenue valued at USD 13 800 per day.

At Wu Long Coal Mine in Liaoning Province, Fuxin Coal Corporation Ltd., they are using 20 M m^3 of highly concentrated CMM to produce 60 GWh of electricity annually. The units also provide space heating for an area of 120 000 m^2 and replace a boiler of 10 t/hr which was used to heat warm water for bathing in the coal mine area.

In 2007, with a total investment capital of over USD 200 million, the largest CMM power plant in the world (120 MW) was developed at the Sihe Coal Mine, owned by the Jincheng Anthracite Coal Mining Group, in the southern part of Shanxi Province. The project was facilitated by an Asian Development Bank loan for nearly 50% of the total capital investment. The project has also built a network of pipelines to capture CMM from other nearby mines for distribution to residential, commercial and industrial consumers in the Jincheng area.

In 2007, Shuicheng Coal Mine Group Ltd. in Guizhou Province developed four local gas systems to supply methane to the residential areas and installed CMM-fired power plants with nearly 19 MW capacity. In 2006, the Group had a CMM utilisation rate of 26%, consuming 44 M m^3 of methane, including 12 M m^3 for residential use and 32 M m^3 for power generation. Electricity generated from CMM was 56 GWh in 2006. Between 1992 and 2006, the Group had combusted 148 M m^3 of methane in total that otherwise would have been emitted into the atmosphere.

The last period, 2005 to present, represents the firm establishment of commercial CMM recovery and use activities in China. There are a number of major projects in operation or in planning, including the largest CMM project in the world, the Shanxi Jincheng power project at the Sihe Coal Mine with 120 MW of electrical output. Further, there are a number of projects in the pipeline for CDM financing (see pp. 23 below). Coal mine owners and operators are investing in CMM projects in increasing numbers; investments include a number of non-power utilisation projects like CMM-to-compressed natural gas. The government has also enacted a number of important policies during this period (see discussion page 24). Primary among them is the government mandate for CMM drainage prior to coal mining activities, which significantly changes the economic feasibility of utilisation projects.

It is clear that China has rapidly advanced to become a world leader in CMM recovery and use. In 1994, only 130 coal mines in China were involved in coal mine methane drainage and recovery activities. By 2007, this number had more than doubled. In 2007, China was estimated to have more than 40 CMM projects, one-fifth of the world's total (US EPA, 2008). While it is difficult to know with certainty the actual status of CMM project development at any time, the US EPA has attempted to summarise the current state of CMM project development (see Table 1).

TABLE 1: ESTIMATED COAL MINE METHANE RECOVERY AND UTILISATION PROJECTS (2007)

	Projects at active mines	Projects at abandoned mines	Total emissions avoided (Mt CO_2e/yr)	Project end use
Australia	10	5	6.4	Flare, power generation, pipeline injection, VAM oxidisation
China	40	0	8.6	Town gas, power generation, industrial application, vehicle fuel, pipeline injection
Czech Rep.	1	0	1.4	Pipeline injection
Germany	9	36	7.5	Combined heat and power, power generation
Kazakhstan	1	0	0.2	Boiler fuel
Poland	21	0	2.1	Power generation, coal drying, combined heat and power, industrial use, boiler fuel
Russia	7	0	0.7	Power generation, boiler fuel
Ukraine	9	0	1.9	Power generation, combined heat and power, industrial use
USA	13	26	16.4	Heating or cooling, pipeline injection, power generation, coal drying, other
Total	**96**	**41**	**45.2**	

Source: US EPA, 2008.

CMM Drainage Technologies and Practices

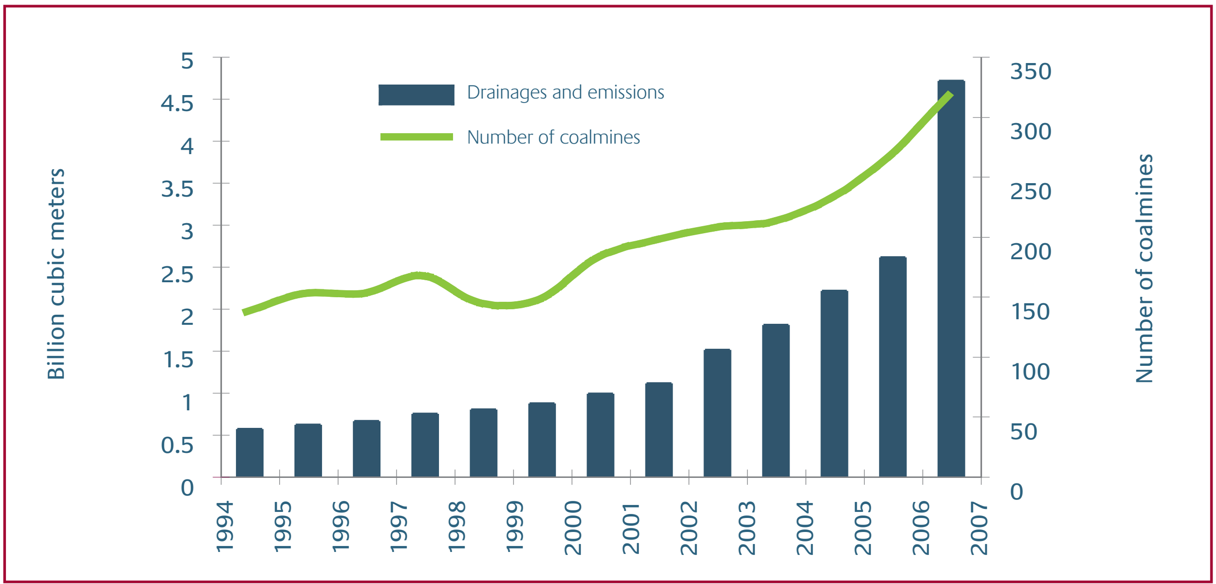
The selection of a suitable CMM gas drainage method in China is mainly determined by factors such as the source of methane, the type of coal, the coal extraction method and the geological conditions. Many coal mines in China are considered to have high gas content. All underground coal mines in China are required to use ventilation systems to keep in-mine methane concentrations below explosive limits and to provide fresh air to the miners. Mines with CMM having methane concentrations over 30% must augment their ventilation systems with drainage or degasification systems to remove methane (see pp. 13 to 15 below).

A number of methane drainage (degasification) techniques have been developed by the international coal mining industry to maximise CMM capture and beneficial use. These techniques can be divided into two basic types:

- Pre-mining drainage, which involves draining gas from coal seams before mining, either from the surface or from inside the coal mine; and
- Post-mining drainage, which involves capturing gas emitted from coal seams in strata above and below a long-wall coal face which have been de-stressed by the mining operation. These boreholes are often called "gob" or "goaf" wells.

Pre-drainage can involve drilling boreholes or wells from the surface into one or more un-worked coal seams and using hydraulic pressure to fracture the coal and allow the release of methane. Most pre-drainage operations in coal mines involve horizontal boreholes drilled in worked seams from underground roadways or, occasionally, from shafts. The benefits sought from application of these techniques include the reduction of gas emissions into development headings, the prevention of explosions, and reduction in gas emissions from worked seams which can be high for thick, high gas content seams.

FIGURE 5: COAL MINES WITH DRAINAGE SYSTEMS AND AMOUNT OF CMM DRAIN



Source: IEA interviews, 2008.

Post-drainage includes methods for recovering methane that is released by mining before it can enter a mine airway. Methane is recovered by drilling from underground passages or exploiting old coal seams. The aim is to consistently capture sufficient gas to ensure that the mine ventilation can satisfactorily dilute any emissions for sake of safe production of coal.

China has rapidly expanded its use of CMM drainage technology in the past decade. Drained and recovered CMM increased from less than 2 billion m^3 in 1994 to 4.7 billion in 2007 (see Figure 5).

Of the methane drained and recovered from Chinese coal mines in 2007, more than 2 billion m^3 of gas was drained in Shanxi Province alone, accounting for 44% of the country's total. About 0.2 billion m^3 was recovered in each of the following provinces: Shaanxi, Liaoning, Anhui, Henan, Guizhou and Chongqing.

A number of CMM drainage technologies and methods have been applied in China. These include in-mine boreholes in the same coal seams, adjacent seam CMM drainage (normally cross boreholes from one coal seam to an upper coal seam), and in-mine gob boreholes. China has faced some important issues and challenges as CMM drainage has expanded. First, in many Chinese coal mines, gas permeability is low and gas pressure is high. As a result, drainage technologies that have worked well in other countries may not be directly applicable in China. In addition, field observations indicate that drills have easily gotten stuck in Chinese coal seams. The length of a drilled borehole in coal seams was usually less than 70 m according to an on-site experience in a coal mine in Guizhou Province and Sichuan Province in China. Therefore, in some cases, the Chinese coal mines have had to increase the size and diameter of the drill and enlarge the power of the drill to meet the specific situation in their coal mines.

In addition, the concentration of methane in recovered CMM in many Chinese coal mines is low; CMM normally has a concentration of 10% to 35%, and a maximum concentration of 60%. Over 70% of the recovered CMM in China has a concentration of less than 30%. This has critical safety implications that directly impact CMM project viability. The explosive range of methane in air is 5% to 15%; as a result, most international CMM project developers do not want to get involved in gas collection and distribution systems that transport gas with a methane concentration below 30% because it is too close to the explosive range.

CMM Utilisation Technologies and Practices

A range of CMM utilisation technologies are used today in China. Coal mines are actively developing technologies to utilise CMM with all ranges of methane concentrations, including:

- High-concentration drained gas (> 80% methane);
- Medium-concentration drained gas, with a methane content of 30% to 80%;
- Low-concentration drained gas, with a methane content of less than 30%;
- Ventilation air methane (VAM), the dilute methane contained in air emitted from the mine ventilation shafts, typically about 1% or less methane.

These technology applications are discussed below.

High-concentration drained CMM. With minimal clean up, high-concentration gas can be injected directly into natural gas pipelines (the most frequent use of CMM in the United States) or converted to liquefied natural gas (LNG). However, high-concentration CMM is not often produced by drainage systems at Chinese coal mines, and China has a very limited natural gas pipeline infrastructure, so this type of CMM is not generally applicable in the country.

Medium-concentration drained CMM. There are several options for use of medium-concentration CMM, including household use, industrial boilers, power generation, and vehicle fuel or LNG. CMM has been used for household gas in several large coal mining cities, such as Fushun city (Liaoning Province) and Yangquan city (Shanxi Province). Huainan Coal Mine in Anhui Province supplies CMM to 100 000 households. This experience indicates that CMM household supply is a good option if gas supply is stable and mines are located close to cities. One disadvantage is the large amount of investment and the long time it takes to construct the necessary infrastructure. CMM has also been supplied to fuel industrial boilers in Jincheng (Shanxi Province) and Huainan (Anhui Province). The method is simple, using CMM for direct fuel combustion in a boiler to generate steam or hot water. This option is suitable mainly at those industrial sites which are close to coal mines. In the vehicle fuel and LNG area, there are a few projects underway in China.

The main type of medium-concentration CMM project in China (and globally) is power generation. CMM power generation projects have been developing rapidly worldwide over the past decade, in countries such as Germany, Australia and the United Kingdom. For example, in September 2006, a CMM power plant began operating at one of Australia's largest coal mines, the Oaky Creek Colliery in central Queensland. Oaky Creek generates a total of 13 MW of power. Similarly, China's CMM power generation is developing rapidly. In 2005, 2.3 billion m^3 of methane was drained; 1.0 billion m^3 was used; and power generation capacity (including plants installed and under construction) reached 200 MW. By 2006, these figures became 3.0 billion m^3, 1.2 billion m^3, and 460 MW. According to the Chinese government plan, China will drain 5 billion m^3 of coal mine methane and utilise 60% of this gas by 2010 (NDRC, 2007).

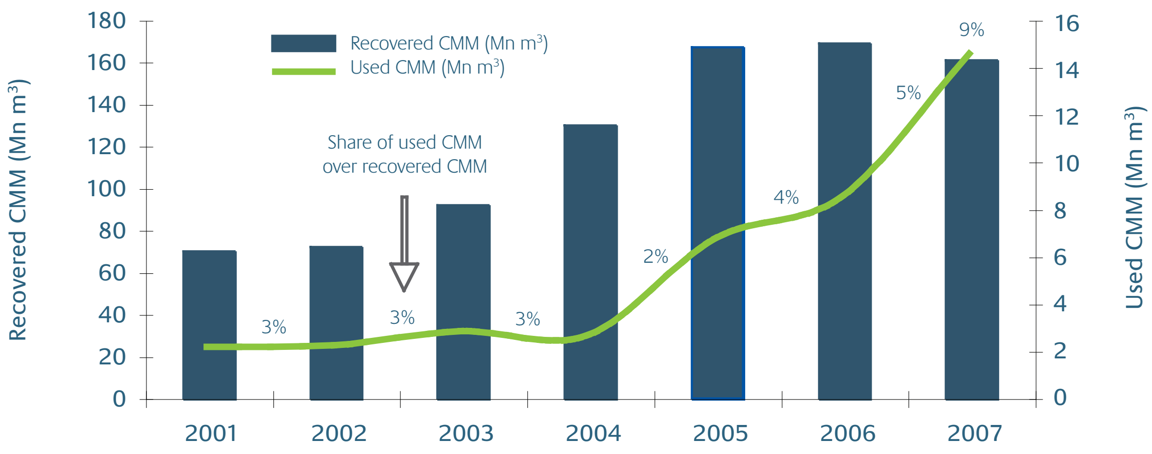
Case Study: Panjiang CMM Project

Background. Panjiang Coal Mine Group Co Ltd. (Group) is a government-owned coal company situated in Guizhou Province of China. There are six pairs of coal mines in production, and two under construction. In 2007, coal output from the Group amounted to 10 million tonnes. Other products and services of the Panjiang Group include coal washing, coal mine construction, geological surveying, machinery repair system, building materials and power generation.

In the coal mining area at Panjiang, there are over 40 coal-bearing seams, but only six to 12 seams are economically feasible for mining (with a thickness of between 5 and 20 m). Total coal reserves are estimated at 9.4 billion tonnes. Panjiang's coal is volatile bituminous. Panjiang's coal appears to have strong prospects for methane recovery and utilisation, with 21 coal seams containing CMM. CMM pressure is between 0.50 and 5.8 megapascal (MPa), and CMM content is from 3.7 ~ 28.8 m^3/t. CMM drained and collected at gob areas may include over 65% of the total coal reserves. As a result, it is estimated that Panjiang Group has a CMM reserve of nearly 25 billion m^3. At present CMM recovery rates (50%), Panjiang Group Co. Ltd can drain and use 12.5 billion m^3 of CMM.

Current situation. In an effort to simultaneously comply with the government requirement to drain CMM prior to mining while also maximising its CMM resources, Panjiang Group has taken an innovative approach to CMM drainage. As of July 2008, Panjiang Group had built 69 degasification wells or boreholes. There are two (high-pressure and low-pressure) drainage systems at each drainage station. CMM drainage capacity is over 4 800 m^3/minute, but the CMM is generally lower-quality (30% methane). Panjiang Group is using a variety of new technologies and practices to maximise the quality of CMM drainage, including underground in-mine boreholes, adjacent seam CMM drainage (normally cross boreholes from one coal seam to an upper coal seam), and in-mine gob boreholes. In addition, the mine is using larger-aperture drills, deep hole blasting of coal seams to increase CMM permeability, and CMM drainage from the ground surface. As a result of this concerted approach, in 2007, the length of construction of gas drainage pipelines was 2.4 kilometers (km) and CMM output per tonne of coal produced reached 16.7 m^3, with an average CMM recovery rate of 51% (see Figure 6).

FIGURE 6: CMM RECOVERY AND UTILISATION AT PANJIANG COAL MINE



Source: IEA Analysis.

CMM utilisation. Panjiang Group started to build the CMM utilisation project in 1996, and has now built four CMM storage tanks with a capacity of 10 000 m^3 each. By July 2008, the Group has installed 8 MW of power generation capacity, and supplies CMM to over 7 000 households. In 2007, total CMM use was 14.6 million m^3, over 9% of the recovered CMM (see Figure 6). Based on this success, Panjiang Group intends to improve its CMM use in the future by taking the following actions:

(1) Increasing investment in low-concentration CMM to power generation to consume the recovered surplus CMM. The Group plans to increase its power generation capacity up to 45 MW;
(2) Working with the local city government to enlarge CMM supply to city and rural households; and
(3) Improving drainage technology and processing to enhance the CMM concentration.

Low-concentration CMM. Methane is an explosive gas in the range of 5% to 15%. Due to safety concerns, there are limited options to use low-concentration CMM (less than 30% methane) globally. While there have been attempts to use CMM at low concentrations in China (see Text Box), many Western project developers and technology vendors do not want to get involved in these projects because of the safety risks associated with transporting, distributing and using the gas near the explosive range of methane.

Chinese Innovation with CMM Technologies

There are a number of power generation technologies that are applicable to CMM power generation using internal combustion engines, including those manufactured by international companies such as GE Jenbacher and Caterpillar. These have been successfully used in China. For instance, the Sihe Mine project generating 120 MW from CMM uses Caterpillar engines. The Huainan Mining Group has power generation capacity using both Jenbacher and Caterpillar engines.

In addition, several Chinese companies have entered this market and have tailored CMM power generation technologies based on CMM quality and mine-specific needs. For instance, Chinese power generation units are available in a range of sizes, including 300 kW to 400 kW, 500 kW, 800 kW, 1.2 MW, 2.0 MW, and 2.5 MW. Shengli Power Company Ltd. and Jinan Diesel Engine Company are the major Chinese firms producing power generators and internal combustion engines using methane as fuel.

Chinese CMM power generation projects have several innovative features:

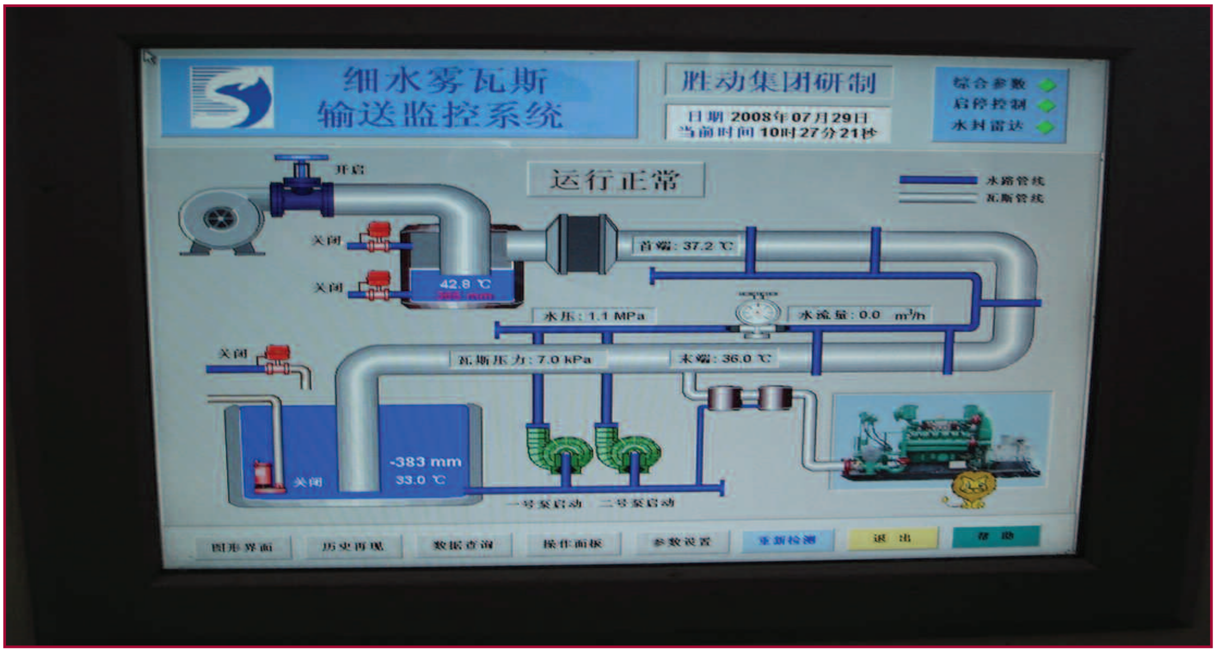
1. Adaptation to variable methane concentrations. The concentration of drained methane varies according to many factors including coal production. To maximise engine efficiency, Shengli Power Company Ltd. has developed a computer programme and a device to control and optimise methane concentration of the input fuel gas.
2. Use of low concentration methane (below 30% methane concentration). One Chinese company, Shengli Power Machinery Company, Ltd. in Shandong Province, has developed a technology to transmit and store low-concentration CMM. This technology, which transmits and uses CMM with a concentration of 6% for power generation, injects water vapour into the CMM gas flow via a special device. When gas transmission is completed, a dehydration device separates the water vapor from the gas, allowing the gas to be used for power generation.
3. Two of the three coal mine methane power generation plants visited during research for this report are using drained gas with methane concentrations in the range of 8% to 10%. Transport or use of coal mine methane in or near the explosive range (e.g., under 30% and over 2%) remains controversial outside of China and is not generally deemed safe.
4. Automation and remote operation. The Chinese have developed an auto-control system for CMM power generation, allowing power plants to be remotely monitored and operated.
5. Relatively low cost. The Chinese power generation technologies are relatively inexpensive; at between USD 270 to 350/kW of power generation facility (this includes the generation unit, control system, and gas pipes, but not the cost of methane drainage).

At the same time, a few technology-specific challenges remain for Chinese CMM power generation technologies:

1. Higher maintenance needs and costs. Since the Chinese technologies are still under development, the power generation plants have a higher need for maintenance. For example, at the Dawan power plant in Guizhou Province, one out of five units was under repair from 2006-07.
2. Performance. On the basis of the on-site inspections conducted for this report, it appears that real power output from these units was on average 10% to 20% less than the amount indicated on the plate of the unit. While this is not outside the range of western experiences, the reasons for this are unclear.

In addition to these power-generation challenges, a number of more broadly applicable barriers to CMM projects in China are discussed on page 28.

FIGURE 7: CHINESE LOW-CONCENTRATION CMM UTILISATION TECHNOLOGY



Source: Ruby Canyon Engineering

Ventilation Air Methane. The large volumes of air with dilute concentrations of methane (typically less than 1%) emitted from mine ventilation shafts constitutes the single largest source of CMM emissions in China. Historically, VAM has simply been released into the atmosphere. Several different thermal and catalytic oxidation technologies to mitigate VAM (i.e., converting methane to carbon dioxide), or even to produce useful heat or electricity from it, have been under development in the United States, Australia and Canada.[7] For example, since 2007, a commercial-scale power plant using VAM has been generating 6 MW of electricity at a coal mine in Australia using a thermal oxidation system. At least one of these technologies has recently been installed in China and several others are under development or are in planning to be demonstrated in China. More work remains to demonstrate the commercial viability of these options.

7. For a summary of technologies, see http://www.methanetomarkets.org/resources/coal mines/docs/cmm_tech_database.pdf.

FIGURE 8: CMM LIQUEFACTION DEMO SITE AT SI GANG COAL MINE, SHANXI PROVINCE

Financing CMM Recovery and Use

Over the past decade, the Chinese government has reduced direct financing of coal projects, including those involving CMM. Before 1998, under the central government planning mode, investments in large coal mines were financed by the Chinese central or provincial governments. In 1998, the Chinese government implemented a reform programme that involved privatising government-owned coal mines. At the same time, private firms were developing quickly. As a result, coal mine operators have become key players in CMM project financing. CMM projects have been increasingly financed through market funds or commercial bank loans and private funds. Table 2 shows the changing trend of CMM project financing at the seven medium-to-small coal mines for which site visits and interviews were conducted for this report.[8] This anecdotal evidence suggests that the central role of government financing on CMM recovery and utilisation has been replaced in part by commercial banks and the private sector.

Case Study on CMM Technology Innovation in China

Key economic and technical data for the demonstration project:

1. Gas input: CMM concentration ≥ 35%, 10 800 m^3 per hour, or 259 200 m^3 per day.
2. Production capacity: 161 m^3 LNG per day, about 65 t of LNG per day. This is equivalent to 90 720 normal cubic meters (Nm^3)/day of natural gas.
3. Total investment: CNY 99 million or USD 14.5 million.
4. Site area: 26 000 m (about 6.4 acres).
5. Power consumption: 4.75 MW (CMM compressor: 700 kW, Nitrogen compressor: 3.65 MW, others 400 kW).
6. Energy intensity (energy consumption per unit output); Power: 1.25 kWh/m— of pure natural gas. Other fuel: 150 m— of CMM with a concentration of 35% as raw material.
7. Annual sale income: CNY 77.1 million (or USD 11.225 million) at a price of CNY 2.5 (USD 0.36) per m— of LNG.
8. Total O&M costs: CNY 55 million (CNY 0.6/m— of raw materials; electricity tariff at CNY 0.46/kWh (or USD 0.067/kWh) and other costs).
9. Average annual profit: CNY 22.5 million or USD 3.25 million.
10. Payback period (before tax): 4.4 years.

Source: Yang K., 2008.

8. Note: the IEA visited 12 mines as research for this report; however, only seven mines produced sufficient data.

TABLE 2: CMM PROJECT FINANCING EXAMPLES

	Starting	Equity		Government Fund		Commercial Loan	
	Year	Share	(M $)	Share	(M $)	Share	(M $)
1. Shuicheng Coal mine Co. Ltd	1992	100%	0	0%	0	0%	0
2. Dengzhanpin Coal mine Ltd. Si Chuan Province	2009	0%	0	0%	0	100%	0
3. Sipin Coal mine No. 1	2008	0%	0	35%	8.141	65%	15.119
4&5. North and South Lu Ban Shan Coal mines Si Chuan	2006	0%	0	50%	2.3	50%	2.3
6. Gu-Lin Coal mine Western Area, Lu Zhou City	2005	0%	0	0%	0	100%	0
7. Gu-Lin County Shan He Coal mine Methane to Power Generation	2008	45%	2.115	0%	0	55%	2.585

Source: IEA interviews with coal mine owners (2008).

There are various means of project financing for CMM projects in China. Financing institutions include international organisations, the national government, provincial governments and private sectors. In addition, international financial institutions can play a key role in capacity building, loan delivery and technology transfer. These organisations include developed country governments, as well as the Asian Development Bank, the World Bank and its Global Environment Facility (GEF). Finally, a growing number of projects in China are taking advantage of the CDM under the United Nations Framework Convention on Climate Change (UNFCCC). Carbon financing, currently almost exclusively through the CDM, has become a very important driver for CMM project development in China (see Text Box).

CMM CDM Projects in China

The CDM, one of the the flexibility mechanisms established under the Kyoto Protocol, allows developed countries listed in Annex 1 of the UNFCCC to invest in GHG emission reduction projects in non-Annex 1 developing countries. Annex 1 countries can then claim the project's Certified Emission Reductions (CERs) to assist them in compliance with their own binding GHG emission reduction commitments under the Protocol. At the same time, CDM project activities contribute to sustainable development in the host developing countries.

CMM projects are one of the leading types of CDM projects, due to their potential for significant GHG credits from a single project. China is the world's leading CMM CDM project host, with 95% of all CMM CDM projects that have been registered to date. However, while there have been a significant number of project applications to the CDM, only eight of the 59 projects submitted have been registered by the CDM Executive Board, and only two CMM projects globally have been issued GHG credits. This is due to a number of challenges that have arisen relating to CMM projects, including the lack of expertise by coal mines in managing CMM utilisation projects; the uniqueness of the CMM resource, which prevents generalisations about gas quality and quantity; and regulations which create confusion about the additionality of CMM recovery and use. Perhaps the greatest barrier to CMM CDM projects and to CMM-use projects in general, is the lack of integration of CMM drainage into the utilisation project from the start. While these barriers are important, they can be overcome. The United Nations Economic Commission for Europe (UNECE) has created an Ad-Hoc Group of Experts on Coal Mine Methane to address these and other issues.

Case study: The first CMM CERs were generated in 2008 at Pansan Coal Mine in Huainan Coal Mine Group Co. Ltd. in Anhui Province of China. The UNFCCC issued a total amount of 196 700 CERs to the Group to acknowledge GHG reductions in the period from 1 October 2004 to 30 September 2007 from the Group's CMM recovery and utilisation projects (Wang Y., 2008).

The major events and activities for this CDM project development were as follows:

1. In August 2004, the United Kingdom government funded a study tour where Pansan Coal Mine engineers and operators visited a number of sites in the UK.
2. In September 2004, the Climate Change Office of the NDRC approved the concept of Pansan Coal Mine's development of CDM projects.
3. In November 2004, Pansan Coal Mines submitted project description documents (PDDs) to the UNFCCC for methodology approval.
4. In October 2005, Huainan Coal Mine Group Co. Ltd. and Norwegian CDM monitoring company DNV signed an agreement to inspect and certify emission reductions from the project.
5. In November 2005, Huainan Coal Mine Group Co. Ltd. (the parent company of Pansan Coal Mines) signed an agreement to sell CERs to Victor Group of Switzerland.
6. On 7 November 2006, the Chinese government formally approved the project.
7. DNV audited the project in March 2006 and submitted its auditing report in December 2006.
8. On 31 March 2007, the Pansan CMM recovery and utilisation project was successfully registered in the UNFCCC.
9. In March 2007, Huinan Coal Mine Group Co. Ltd. signed an agreement with Tianfu Nande (TUV) Beijing Company for CER reduction verifications.
10. In July and August 2007, a TUV team performed on-site verification activities.
11. On 4 February 2008, the first CERs (76 000 t of CO_2 equivalent) were issued.
12. On 4 June 2008, the second set of CERs (120 700 t of CO_2 equivalent) was issued.

The Pansan CDM project demonstrates the viability of CDM project financing to CMM recovery and utilisation projects in China. However, this experience also demonstrates the length of time it takes for a coal mine to get CERs, as well as the different government, private and auditing expertise that is needed.

Source: Wang Y., 2008

Relevant Policies on Coal and CMM Recovery and Use

Over the past several years, the Chinese government has enacted a number of energy and environmental policies that affect coal development and CMM recovery and utilisation. In addition to the National Framework policies on energy saving and the environment, there are policies to improve the administrative framework for energy resource and environmental management. Further, new government policies aimed at reducing methane venting at coal mines have had an important impact.

The government has made a great number of policies and regulations in the areas of development, planning, sustainability, safety, royalty tax reforms, coal mine methane and coal bed methane recovery and utilisation. Relevant policies are summarised below.

Coal Mining Policies

Significant policies in China's coal industry development include policies to enhance industrialisation in coal production, and to develop coal groups to build capacities in business administration, financing and production for large coal mines. In the coming years, China will create eight coal mining groups with the capacity to produce 100 million tonnes of coal per annum, as well as another ten coal groups with an annual production of 50 million tonnes each. By 2010, China will build 13 large coal mine bases, with coal production of 2.2 billion tonnes per annum, a share of about 86% of the total national production (Wang X. Z., 2008).

The government also aims to transition to the use of modern technology in coal mines, using coal excavation mechanisation at over 95% of large-scale coal mines, 80% at the medium-scale coal mines, and 40% at smaller coal mines. To achieve this goal, China further enlarged technology investment, promoted scientific research to tackle key issues in manufacturing efficient coal mining technologies, including open-cast mining equipment, large-scale transportation equipment, coal washing equipment and coal mine methane recovery and utilisation.

Further, since 2005, the government of China has implemented a policy to reform and optimise the structure of coal industry. By the end of 2007, China had closed over thousands of small[9] coal mines with total annual production capacity of 250 million tonnes. In the next several years, the government will continue in this effort, with a goal to have less than 10 000 small coal mines by year 2010, with less than 700 million tonnes of total production from these small mines.

Coal Mine Methane Drainage and Recovery Policies

To address coal mine safety, in June 2006, the State Council issued Opinions on Speeding up CBM/CMM Extraction and Utilisation, which clarified the guiding principle of gas extraction prior to coal mining, integrated with gas control and utilisation. The policy requires that local land and planning authorities ensure that coal

9. It is difficult to find an official definition for "small" coal mines in China; therefore, this term is used qualitatively in this report.

mines implement a safety first approach, focusing on prevention, safety standards and oversight by the government, and the use of technology.[10] Key aspects of this policy are:

- Coal mine methane must be drained first, prior to coal mining;
- Coal mines must implement CMM measurement and monitoring activities;
- Coal production activity is not allowed without a CMM drainage system; if there are significant problems caused by coal mine methane, mining activity must be suspended; and
- Coal mine owners and operators have legal responsibilities to ensure that these standards are followed.

Based on the limited set of interviews conducted for this report, this policy appears to be implemented successfully by coal mine owners and operators in Guizhou and Sichuan Provinces.

FIGURE 9:
LOW GAS QUALITY 500KW SHENGDONG ENGINE

Source: Ruby Canyon Engineering

In addition to this policy, in April 2008, the Ministry of Environmental Protection issued an Emission Standard of CBM/CMM, which became effective on 1 July 2008 for new coal mines and surface drainage systems, and will become effective on 1 January 2010 for existing mines/systems. This new standard dictates the following:

1. CBM drainage systems are prohibited from emitting CBM;
2. Coal mine drainage systems with a gas concentration having 30% methane or higher are prohibited from emitting the methane (e.g., they must either use or flare the gas); and
3. If the methane concentration is less than 30%, the methane is allowed to be released.

This is an important policy that on its face appears to support greater use (or flaring) of CMM. However, it was observed during interviews and site visits that this new policy may actually create an incentive to dilute CMM to avoid the flaring/use requirement, leading to a greater risk of explosion from lower-concentration CMM streams.

10. See http://www.chinasafety.gov.cn/zuixinyaowen/2008-08/08/content_285865.htm.

CMM Utilisation Policies

The 11th Five-Year Plan for CBM/CMM Development and Utilisation (NDRC, June 2006) proposes (among other objectives) that by 2010, the national CBM/CMM output should reach 10 billion cubic meters (bcm) via the establishment of a formal CBM/CMM industry. To aid in implementing this goal, in April 2007, NDRC issued a Notice on CBM/CMM Price Management. It specifies that the price of gas that is not distributed via city pipeline networks can be determined freely through negotiations, while the price of gas distributed via city pipeline networks and operations under government control should be determined according to its heating value (compared to substitute fuels such as natural gas, coal gas and liquefied gas). Also in the same month, NDRC issued a Notice on Executing Opinions on Generating Electricity with CBM/CMM. This encourages the deployment of power generation projects with CBM/CMM. The notice requires that electricity generated by CBM/CMM power plants should be given priority by grid operators who should purchase surplus electricity at a subsidised price, as specified by NDRC in the Trial Management Method for Electricity Prices and Sharing Expenses for Electricity Generated with Renewable Energy. CBM/CMM power plant owners were also exempted from market price competition and do not undertake any responsibilities for grid stability.

At the same time, in April 2007, the Ministry of Finance issued Executing Opinions on Subsidising CBM/CMM Development and Utilisation Enterprises whereby any enterprise engaged in CBM/CMM extraction within China is entitled to financial subsidies, if it is used on site or marketed for residential use or as a chemical feedstock. CBM/CMM used to generate power does not benefit from this subsidy.

Further, CMM power generation projects listed in the Catalogue of Comprehensive Utilisation of Resources (2003 revision) are eligible for certain preferences. Power authorities will grant enterprises co-generating electricity and heat from CBM/CMM a grid connection if the individual units have an installed capacity of above 500 kW and meet required standards. They are exempt from paying the connection fee normally charged to small-scale, coal-fired power plants; they are excluded from quotas under the national distribution plan; and they benefit from priority electricity sales to the grid at wholesale prices, or even at higher prices if approved by the provincial authorities. Those with an installed capacity of 1.2 MW or less are not required to support the grid by load following. Plants above this capacity can deliver their full output during periods of peak demand, but will never be required to drop below 85% output.

Other Policy Support

In addition to the previous policies, the Chinese government has developed a number of supporting policies to promote CMM recovery and utilisation. They are summarised as follows:

- Under the National Land Transfer Policy, land use priority is given to CMM recovery and utilisation projects;
- Coal mine companies with CMM drainage and recovery systems are allowed to use production safety funds to invest in CMM drainage and utilisation;
- Governments at all levels are encouraged to provide discounted loans or grants to CMM projects;
- The value-added tax levied from coal mines which recover and utilise CMM is returned to the coal mine operators (returned taxes are to be used in R&D and investment in coal mine for enlarged production);
- No income tax shall be levied for enterprises which are developing technologies for CMM recovery and utilisation;

- For installed CMM recovery and utilisation equipment, a unified method of depreciation of "double declining leftover value" can be applied to accelerate capital depreciation;
- If a coal mine owner or developer invests capital in CMM projects via loan or self equity finance, it can claim 40% of the capital value to offset its income tax; and
- Import-related taxes and value-added taxes are exempted for CMM exploration and development operations and equipment.

Policy Impacts and Implementation

Some of the policies listed above have had important impacts on CMM recovery and use in China; however, others have not been implemented effectively. For example, site visits and interviews confirmed that the government's mandatory policy for pre-drainage of CMM in coal mines has had positive impacts on China's coal sector. All of the mines visited were developing CMM drainage systems at their underground coal mines to comply with the government policy. The provincial coal mine safety administration bureaux play a key role in implementing this policy, which is expected to significantly reduce the number of annual deaths in coal mines. Thus, it will offer strong incentives for implementation by local government officers, who receive recognition for superior safety records.

In contrast, the new policy requiring methane use if CMM concentrations equal or exceed 30% appears to be creating uncertainty for CMM utilisation projects. Based on anecdotal reports gained from the interviews, this policy may result in an increase in CMM dilution to avoid the requirement of flaring/use.

Similarly, the government's policies providing priority grid access and/or subsidies to CMM power are not being effectively implemented. Under this policy, the power companies must buy surplus CMM electricity at favourable rates. However, in Guizhou and Sichuan Provinces, none of the coal mines that were visited for this report have sold electricity to the power grids, even though the mines have surplus electricity and are interested in selling it. This outcome may be the result of improper incentives: when buying CMM electricity, power distribution companies were not able to make a profit. As a result, the distribution companies requested that the CMM electricity providers pay an additional fee for the use of power distribution network; the coal mine operators considered this fee too high to be affordable. It is also unclear from our research whether the tax and other financial benefits policies are well-known and/or implemented at the provincial level.

Organisational Roles and Responsibilities for CMM in China

CMM recovery and use stakeholders in China include the national government, provincial governments, the private coal mining companies, project developers and equipment suppliers, and research institutions and universities.

The National Government

The roles and responsibilities within the national government on coal and coal mine methane have changed dramatically over the past half century. From 1949–98, China's major coal mines were planned and run by the central government. The private sector played limited roles in coal mine development. Responsibilities of coal mine development and management were always under the former Ministry of Coal Industry.

Beginning in 1998, China implemented many reforms in the coal sector. The government dissolved the Ministry of Coal but did not shift the government responsibilities of management to any other ministries, except macro-policy management roles and responsibilities to the NDRC. The role of NDRC today is to make national development macro-policy, including CMM recovery and utilisation policies. To carry out some of the responsibilities of the former Ministry of Coal of China, the State Administration of Work Safety (SAWS), and the State Administration of Coal Mine Safety (SACS) were created. These are actually two parts of the same organisation.[11] The SAWS/SACS reports to the State Council, the non-ministerial agency responsible for the regulation of risks to occupational safety and health in China. SACS develops and publishes national codes and regulations on safety production, and monitors the implementation of these codes. In provinces and cities, SACS has corresponding sub-organisations. These sub-organisations also implement NDRC's national macro-policies, because the provincial development and reform agencies do not manage coal mine safety and CMM recovery and utilisation issues.[12] Coal mine safety production regulations and codes and policies are originally developed by SAWS, published by the State Council and the NDRC, and implemented by the provincial administrations of coal safety. SAWS also has its own research institutions and universities in the country.

China Coal Information Institute (CCII) is one of these institutions. The CCII, which was the former China Coal Scientific and Technical Information Institute, provides information services such as information research and dissemination, book and journal publication, audio-video production, patent service and coal-related science, and technology and knowledge dissemination.

Local Governments and the Private Sector

Local governments and the private sector, in particular, are playing an increasing role in coal production in China. Local governments are defined as government agencies at the provincial and county levels. The private sector consists of all the non-governmental parties including coal mine investors, developers, owners, operators, coal transporters and distributors, and coal production–related equipment developers and producers.

Barriers to CMM Recovery and Beneficial Use

Although the Chinese government and the coal industry have shown strong growth over the past 15 years in CMM recovery and utilisation, there is still tremendous potential for growth in the future, with corresponding energy supply and environmental benefits. However, based on evidence collected in the course of research for this report in some key coal mining provinces, in order for this growth to be realised, a number of barriers must still be addressed.

11. SAWS and SACS website: http://www.chinasafety.gov.cn/.
12. IEA interview with the NDRC and provincial government agencies in 2008.

Potential Contradictions in Policies on Drainage and use of CMM

Methane drainage and capture in many Chinese coal mines are being driven by the new safety policy that prioritises CMM drainage. However, while the new policy that requires use of CMM with 30% or greater methane may appear to complement the "drainage first" policy, initial anecdotal evidence appears to support the opposite conclusion: that mines may dilute their CMM streams to avoid the requirement. This will possibly lead to an increased safety concern due to the growth in the venting and piping of lower-quality CMM below 30% (see below).

Lack of Implementation of Subsidy and Grid Access Policies

As a result of the "drainage first" policy, the amount of methane drained and captured at mines has increased with the increase of coal production; but utilisation has not followed suit, due to a lack of incentives for beneficial use. As explained above, the subsidies and priority grid access policies that were enacted in April 2007 are not being enforced. For instance, none of the interviewees for this study were aware of a project that has received the subsidy, suggesting that it has not been widely publicized or exercised.

Lack of Information and Expertise on CMM Power Generation at Smaller Mines

Methane recovery and utilisation is relatively new to most of the coal industry in China, particularly at medium-to-smaller mines. At the coal mines that were visited in Guizhou and Sichuan Provinces, nearly 35% of the available CMM was captured and utilised. While this is a good start, few, if any, of the small coal mine operators had the necessary knowledge and expertise in using coal mine methane for power generation. For example, they did not know what size (in electrical capacity) power plant should be installed to fully use their coal mine methane. It was also difficult for them to hire skilled workers to run a power plant; people working in these coal mines are from local, impoverished rural communities where few educated outsiders are willing to live and work.

Transport and Use of Low-Quality CMM (<30% Methane)

Most Chinese coal mines with drainage systems produce CMM that is generally lower in quality (e.g., often less than 30%) compared to gas produced from mine drainage systems in other coal mining countries such as the United States or Australia. Some key factors leading to this low quality gas production include inadequate drainage technologies and systems that are insufficient to remove methane from highly impermeable Chinese coal seams, as well as "leaky" gas collection systems. While several Chinese companies have innovated to recover and use CMM that is near (or in many cases, actually in) the explosive range of methane, outside of China this practice is nearly universally viewed as unsafe. In particular, the transport of gas in or near the explosive range of methane underground or near the underground workings is of primary concern because of the potential for a methane explosion underground. Better understanding of strategies to improve mine degasification at Chinese coal mines would help avoid this situation, and prevent the potential risks associated with transporting and using this low-quality gas.

Limited Knowledge or Utilisation of Technology to Mitigate or Recover Ventilation Air Methane

Ventilation air constitutes about 60% or 70% of all CMM that is released to the atmosphere. Concentrations of VAM in China are typically well below 1%. Because mitigation or energy recovery from VAM is a cutting-edge technology and has only been demonstrated at a few sites globally, Chinese coal mines have limited experience in using VAM as a clean energy resource. Based on the interviews for this study, coal mine owners and operators in Sichuan and Guizhou Provinces were very interested in VAM oxidisation technologies when they learned about the potential to generate CERs and electricity for the coal mines. As China and other countries gain experience with VAM mitigation and energy recovery at coal mines, more technology transfer and information exchanges will be useful to inform Chinese coal mines about this opportunity.

Shortage of Suitable Smaller-Scale Internal Combustion Engines

In Guizhou and Sichuan Provinces, there are a large number of private and small coal mines. Coal output from each of these small coal mines is about 100 000 t/year. Methane from such a coal mine is not enough to drive a 400 kW unit, but could power a unit of 150-200 kW. However, it is currently difficult to purchase a micro-IC engine with this capacity in China. In a national government white paper (NDRC, 2007), power generation facilities with a capacity of less than 500 kW per unit are not encouraged in China. This policy does not support CMM use at smaller coal mines.

Lack of CMM Gas Use Opportunities

Many Chinese coal mines are located in isolated rural areas. It is not financially viable to transmit methane via pipeline long distances from these remote mines to large cities that can provide the market for this gas. The local residents are sparsely populated and have very limited purchasing power to use piped methane. Even for large coal mine operators, supplying methane to households that are beyond the immediate border of the mine is, in many cases, not feasible. For instance, none of the mines visited for this study was connected to a commercial gas market; all the methane drained and collected in coal mines was either used within the borders of the coal mines or vented to the atmosphere.

High Transaction Costs Associated with Small CDM Projects and Lack of a Policy Framework for the Promotion of Small-Scale CDM Projects

Based on an interview with a representative of the Sichuan Provincial government, there currently do not appear to be successful CMM-related CDM projects in the Sichuan Province. The major barriers cited were high transaction costs, long lead times, and low expected revenue from smaller CDM CMM projects. The representative suggested a solution of bundling small Sichuan projects into one larger CDM project to reduce transaction costs.

Policy Recommendations

It is clear that China has come a long way in the past 15 years in developing capacity for CMM recovery and use. It now hosts some of the world's largest successful CMM projects, and other policies (notably the "drainage first" policy) are being successfully implemented at the national and local levels with real safety benefits. However, due to the rapid expected growth in China's coal use, the country's overall coal mine methane emissions will continue to rise, leading to increased GHG emissions and a lost opportunity for a "free" source of fuel. A more concerted effort toward CMM utilisation would offer China many local and global benefits. Therefore, this report makes a number of recommendations on strategies that can be pursued to address the key barriers, and ultimately increase the viability and success of Chinese CMM capture and utilisation in the future. These recommendations include areas of continued government reform, involving all stakeholders in CMM recovery and utilisation, including capacity building for medium and small coal mines in remote areas.

Continued Government Attention to CMM Use

China's energy and CMM recovery and utilisation policies are largely formed by the State Council of China and the NDRC, with support from other Ministries such as the Ministry of Finance and the State Administration of Worker Safety. The lower levels of the State Council and the NDRC (provincial development and reform commissions) have very few responsibilities or authority to encourage or regulate CMM recovery and utilisation. As a result, some national policies on CMM recovery and utilisation – including important policies on CMM utilisation, subsidies and priority access – are not being executed. The provincial governments play a key role in implementing national policies, through the Provincial Coal Mine Safety Bureaux. These Provincial Bureaux have the right to shut down mines that do not comply with government safety policies. They also have strong local contacts with the relevant coal mining stakeholders, including, in particular, the smaller mines that lack the knowledge and expertise to implement CMM projects.

It is recommended that the NDRC's provincial development and reform commissions, together with the provincial safety bureaux, prioritise CMM education and outreach. The provincial governments in key coal provinces could explore the creation of a dedicated office to represent the interest of coal mines in the province. This office could be tasked with a variety of duties, including information dissemination, training and outreach, as well as negotiation of CDM projects with international investors. This will reduce the transaction costs of project development for individual mines.

Involving Stakeholders in CMM Subsidy and Grid Access Policy Development

In the current CMM policy, not all key stakeholders are involved. This has made policy implementation difficult. For example, the policy regarding priority access of CMM power to the grid has not involved the China State Power Network Group Corporation, the key grid stakeholder that manages China's power transmission network. To date, the China State Power Network Group Corporation has not actively participated in the development of the national CMM policy papers and, therefore, is not supportive of the incentive structures that are included in these policies.

To resolve this issue, it is recommended that the State Council or the NDRC involve the China State Power Network Group Corporation and the Ministry of Finance and other stakeholders while making CMM policies regarding grid access and incentives. One possible approach would be to stipulate that when a power grid company pays a subsidy to a CMM power producer, the power grid company should be compensated from other government financial resources.

Capacity Building in CMM Recovery and Utilisation at Smaller Coal Mines

Given that nearly all smaller coal mines lack basic understanding and expertise in CMM recovery and utilisation, it is recommended that the provincial governments develop capacity building efforts in technologies, mine operation and economic analysis of projects. The World Bank and Asian Development Bank, as well as bilateral donors, may be interested in providing resources and expertise through targeted training workshops on CMM recovery and utilisation technologies and practices. In addition, policies should be developed to keep qualified engineers and skilled workers running CMM recovery and utilisation projects at smaller coal mines.

Continue to Adapt International CMM Technologies to Chinese Circumstances

It is clear that some coal mines and equipment suppliers are already at work on ways to tailor international technologies and practices for CMM to the Chinese situation. In addition, Chinese experts are also researching and adapting innovative CMM-use technologies that show promise, including use of lower-quality CMM (and VAM) and CMM liquefaction. However, more could be done to share international best practices, and to tailor these technologies to the situations found in Chinese coal mines. If the provincial governments expand their capacity for outreach and engagement on CMM recovery and use, this could be one important focus area. There are international networks such as the Methane to Markets initiative[13] that are designed to share these sorts of national experiences; it is recommended that Chinese government and industry stakeholders take advantage of this knowledge resource, and also share Chinese experiences more widely around the world.

13. See www.methanetomarkets.org.

Abbreviations and Acronyms

APEC: Asia-Pacific Economic Co-operation
CBM: Coalbed methane
CCII: China Coal Information Institute
CDM: Clean Development Mechanism
CER: Certified Emission Reductions
CH4: Methane
CMM: Coal Mine Methane
CNN: Chinese Yuan
CO_2: Carbon dioxide
EU: European Union
GDP: Gross domestic product
GEF: World Bank Global Environment Facility
GHG: Greenhouse gas
IPCC: Intergovernmental Panel on Climate Change
LNG: Liquefied natural gas
NDRC: National Development and Reform Commission
O&M: Operation and maintenance costs
PPM: Parts per million
SAWS: State Administration of Work Safety
SACS: State Administration of Coal Mine Safety
TUV: Tianfu Nande
UNDP: United Nations Development Programme
UNECE: United Nations Economic Commission for Europe
UNFCC: United Nations Framework Convention on Climate Change
US EPA: United States Environmental Protection Agency
VAM: Ventilation air methane

Units

Bcm: Billion cubic meters
m: Meter
GWh: Gigawatt-hour
kW: Kilowatt = 103 watts
kWh: Kilowatt-hour
M m^3: Million cubic meters
MPa: Megapascal
Mtoe: Million Tons of Oil Equivalent
MW: Megawatt
M^2: Square meter
m^3: Cubic meter
Nm^3: Normal cubic meter. Measured at 0 degrees Celsius and a pressure of 1.013 bar.
t: Tonnes

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