ESM326

Formal Report 326/07

A Strategy for Coal Bed Methane (CBM) and Coal Mine Methane (CMM) Development and Utilization in China

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ESMAP

Energy Sector Management Assistance Program

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Funding

ESMAP is a knowledge partnership supported by the World Bank and official donors from Belgium, Canada, Denmark, Finland, France, Germany, Iceland, the Netherlands, Norway, Sweden, Switzerland, United Kingdom, United Nations Foundation, and the United States Department of State. It has also enjoyed the support of private donors as well as in-kind support from a number of partners in the energy and development community.

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Energy Sector Management Assistance Program (ESMAP)

Produced in India
First printing July 2007

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Preface

Globally, Coal Bed Methane/Coal Mine Methane (CBM/CMM) is attracting growing attention mainly from the perspective of climate change. However, China has two additional and very compelling reasons for addressing the issue – reducing coal mine fatalities and developing cleaner energy resources to improve air quality in cities.

In 2004, coal production in China resulted in the release of an estimated 18 billion cubic meter (Bm^3) Methane (CH_4) (equivalent to 271 Million Tons (10^6) Mt Carbon Dioxide [CO_2]), representing 43 percent of global CH_4 released by the coal mining industry, and accounting for more than a third of China's emissions of anthropogenic methane. CH_4-related explosions killed some 2,000 coal miners, whereas it is estimated that more than 400,000 Chinese died prematurely because of urban air pollution. Since coal will continue to meet most of China's growing energy needs, even with an aggressive fuel diversification policy and energy efficiency efforts, the amount of CMM released by coal mines is bound to increase some 2/3 above the present level by 2020.

China has realized that Greenhouse Gas (GHG) emissions and other air pollutants will cause unacceptable local, regional and global environmental problems unless it makes a major effort to reduce. The government has shown strong commitment to CBM and CMM development and utilization, and they are a priority in China's 11th Five-Year Energy Development Plan. Better control and use of CMM is now the cornerstone of the central government's strategy to step up coal mine safety. However, the government has yet to introduce and implement specific policy measures and institutional changes to achieve the desirable results.

This Energy Sector Management Assistance Program (ESMAP) activity aims at improving and understanding the status of the CBM/CMM investment and development in China as well as the governing legal and regulatory framework, identifying the institutional policy and technical barriers which need to be addressed and suggesting a series of actions which the government needs to take to significantly scale up the development and utilization of CBM/CMM. The report is not intended to provide a detailed blueprint. However, it does provide recommendations, rationales and options for certain institutional and policy choices which will have to be made as well as suggestions for detailed studies to implement them.

In publishing this volume, we very much hope it proves to be useful to the various government agencies and institutes in China as well as the international community which is interested in China's energy and environment, particularly the CBM/CMM industry.

Acknowledgments

This report presents the results of a study undertaken by the Energy and Mining Development Sector Unit, East Asia and Pacific Region of the World Bank, with financial support from ESMAP. The report was primarily prepared by Mr. David Creedy (independent consultant) and Mr. Jianping Zhao, Energy and Mining Development Sector Unit, East Asian and Pacific Region of the World Bank, with substantial inputs from Mr. Shenchu Huang and Mr. Wenge Liu of China Coal Information Institute (CCII).

The team gratefully acknowledges the review and valuable comments of the four peer reviewers: Mr. John Strongman, Adviser, Oil, Gas, Mining and Chemical Department, The World Bank; Mr. Masaki Takahashi, Senior Power Engineer, Energy and Water Department, The World Bank; Mr. Ray Pilcher, President, Raven Ridge Resources Incorporated (Inc.); and Ms. Pamela Franklin, Team Leader, Environmental Protection Agency (EPA), U.S.A. Insightful comments and suggestions were also provided by Ms. Dominique Lallement, Adviser, Energy and Water Department, The World Bank.

An international CBM/CMM forum was organized by CCII on behalf of the State Coal Mine Safety Supervision Administration (SCMSSA) of China, The World Bank and EPA, U.S.A.

The team is indebted to Mr. Wu Yin, Mr. Wang Yang and Mr. Zhao Weiguo from the National Development and Reform Commission (NDRC) for their support and assistance.

The team benefited greatly from fruitful discussions with many government officials, particularly from NDRC, the Ministry of Land and Resources, the Shanxi Provincial Development and Reform Commission (PDRC), Shanxi Finance Bureau, Jincheng Municipal Government, Shanxi Energy Enterprise Group as well as representatives of many mining groups together with individuals from Sino Gas & Energy, BHP Billiton, Chevron, Fortune Oil Plc and Clear World Energy in the private sector.

The following World Bank staff also provided advice, comments, inputs and support: Mr. Robert Taylor, Mr. Charles Leva, Ms. Veronique Bishop, Mr. Bert Hofman and Mr. Chunxiang Zhang. Editorial, publication and distribution support was provided by Ms. Marjorie K. Araya and Ms. Ananda Swaroop from the ESMAP Communications Team. The Team is grateful for the support and guidance extended to this work by the management of the East Asia and Pacific Region's Energy and Mining Sector Development Unit, the China Country Program and the World Bank's Energy and Water Department.

Units of Measure

Bm^3	Billion Cubic Meters (10^9)
Bt	Billion Tons
C	Carbon
CH_4	Methane
C_2H_6	Ethane
C_3H_8	Propane
CH_3OH	Methanol
CO_2	Carbon Dioxide
DME	Di-Methyl Ether
Gt	Giga Ton (10^9 Tons)
GJ	Giga Joules (10^{12} Joules)
GWh	Giga Watt (s) Per Hour
km	Kilometer
km^2	Square Kilometer
Kt	Kilo Tonnes (100 Metric Tonnes)
ktpa	Thousand Tons Per Annum
kW	Kilo Watt (s)
m	Meter
m^3	Cubic Meter
m3/t	Meters Cubed Per Metric Tonne
Mt	Million Tons (10^6)
Mtce	Million Tons Coal Equivalent
Mtpa	Million Tons Per Annum
MW	Mega Watt (s)
MWe	MW Electricity
MWh	Mega Watt (s) Per Hour
N	Nitrogen
N_2O	Nitrous Oxide
PJ	Peta Joules (10^{15} Joules)
t	Ton
Tm^3	Tera (Trillion) Meters Cubed (10^{12})

Conversion Factors

66.4m^3 Methane (NTP) equivalent to 1 ton CO_2
C equivalent to CO_2 equivalent, multiply by 3.6667.

Acronyms and Abbreviations

AACI	Asian American Company Inc.
ADB	Asian Development Bank
AMM	Abandoned Mine Methane
ARCO	Atlantic Richfield Company (petroleum)
ASEAN	Association of South-East Asian Nations
CAIT	Climate Analysis Indicators Tool
CBM	Coal Bed Methane
CCERC	Clean Coal Engineering & Research Centre
CCGA	China Coal Geological Administration
CCIA	China Coal Industry Association
CCII	China Coal Information Institute*
CCRI	China Coal Research Institute
CDM	Clean Development Mechanism
CERs	Certified Emission Reductions
CHP	Combined Heat and Power
CMM	Coal Mine Methane
CMOP	Coalbed Methane Outreach Program (U.S.)
CNCA	China National Coal Association
CNPC	China National Petroleum Corporation
CNG	Compressed Natural Gas
CSIRO	Commonwealth Scientific Industrial Research Organisation (Australia)
CUCBM	China United Coalbed Methane Company Limited
DNA	Designated National Authority
DTI	Department of Trade and Industry (U.K.)

* *Now renamed National Institute for Occupational Safety (NIOS).*

EB	Executive Board
EC	European Commission
ECBM	Enhanced Coal Bed Methane
EEG	Erneverbare Energien Gesetz
EPA	Environmental Protection Agency
ERI	Energy Research Institute
EU	European Union
FIs	Financial Institutions
FCO	Foreign and Commonwealth Office (U.K.)
GDP	Gross Domestic Product
GECs	Gas Electricity Certificates (Australia)
GEF	Global Environment Fund
GGAP	Greenhouse Gas Abatement Programme (Australia)
GHG	Greenhouse Gas
HSE	Health and Safety Executive
IGS	Institute of Geological Survey
Inc.	Incorporated
IPR	Intellectual Property Rights
IPCC	Intergovernmental Panel on Climate Change
JCAO	Japan Coal Energy Center
JMG	Jincheng Mining Group
JVs	Joint Ventures
KSOCM	Key State-owned Coal Mine
LNG	Liquefied Natural Gas
MA	Mei Anquan (coal safety mark of approval)
MDL	Methane Drainage License
MoLaR	Ministry of Land and Resources
MOST	Ministry of Science and Technology
MRI	Mitsubishi Research Institute
M2M	Methane to Markets (Partnership)
NAFTA	North America Free Trade Agreement
NCBP	North China Bureau of Petroleum
NCCCC	National Communication on Climate Change of China
NDRC	National Development and Reform Commission
NGACs	New South Wales Greenhouse Gas Abatement Credits
NSB	National Statistics Bureau

OEM	Original Equipment Manufacturer
PDRC	Provincial Development and Reform Commission
PEDL	Petroleum Exploration and Development Licenses
PSC	Production-Sharing Contract
PTC	Production Tax Credit
R&D	Research and Development
RE	Renewable Energy
RETs	Renewable Energy Technologies
SACMS	State Administration of Coal Mine Safety
SAWS	State Administration of Work Safety
SCMSSA	State Coal Mine Safety Supervision Administration
SCWSC	State Council Work Safety Commission
SETC	State Economic and Trade Commission (now abolished at State level)
SOCM	State-owned Coal Mine (city or county government owned)
SOE	State-Owned Enterprise
STIS	Surface to in-seam (drilling)
TVCM	Town and Village Coal Mine
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VAM	Ventilation Air Methane
VAT	Value Added Tax
VCBM	Virgin Coalbed Methane
WB	World Bank

Glossary of Terms

Abandoned Mine Methane (AMM): gas produced from abandoned coal mine workings through abandoned mine entries and from boreholes drilled into underground roadways or former workings.

AMM resources: the volumes of gas remaining in coal seams which have been destressed by mining and which could potentially be extracted from abandoned mine workings. Reserves are the volumes of gas expected to be recoverable having taken account of groundwater recovery.

Capture efficiency: the proportion of methane by volume captured in a methane drainage system relative to the total quantity of gas released (comprising drained gas and gas emitted into the mine ventilation air) expressed as a percentage. Drainage efficiency can be determined for a single longwall panel or for a whole mine.

CBM resources: gas in place within all coal seams within a designated depth range at which the gas is potentially recoverable.

CBM reserves: gas in coal seams which can be demonstrated as economically recoverable.

Coal Bed Methane (CBM): a generic term for the CH_4-rich gas naturally occurring in coal seams typically comprising 80 percent to 95 percent CH_4 with lower proportions of Ethane (CH_2H_6), Propane (C_3H_8), Nitrogen (N) and CO_2 depending on the coal rank. In common use, it is applied to CH_4 recovered from unmined coal seams using surface boreholes.

Coal Mine Methane (CMM): gas captured at a working coal mine by underground CH_4 drainage techniques. The gas consists of a mixture of CH_4 and other hydrocarbons and water vapor. It is often diluted with air and associated oxidation products due to unavoidable leakage of air into the gas drainage boreholes or galleries through mining induced fractures and also due to air leakage at imperfect joints in underground pipeline systems. Any gas captured underground whether pre- or post-drained and any gas drained from surface goaf wells is included in this definition. Predrained CMM can be of high purity.

CMM resources: the volumes of gas in coal seams which will be released by planned longwall extraction over the life of a mine. The technically recoverable CMM reserves are the volumes of usable gas which can be captured by CH_4 drainage systems and delivered to a utilization plant.

Goaf: broken, permeable ground where coal has been extracted by longwall coal mining and the roof allowed to collapse thus fracturing and destressing strata above and, to a lesser extent, below.

Key State-Owned Mines (KSOCMs): coal mines formerly under the aegis of the Ministry of Coal Industry of central government.

Ownership was transferred to provincial and regional governments on abolition of the Ministry of Coal Industry.

CH_4 drainage: methods for capturing the naturally occurring gas in coal seams to prevent it from entering mine airways. The gas can be removed from coal seams in advance of mining using predrainage techniques and from coal seams disturbed by the extraction process using postdrainage techniques.

Natural gas: gas extracted from geological strata other than coal seams. Nevertheless, the gas could have originally migrated from coal seam sources.

Technically recoverable gas: the estimated volume of gas that could be recovered using available technology (sometimes termed potentially recoverable gas).

Ventilation Air Methane (VAM): CH_4 emitted from coal seams, which is not removed before mining or captured, enters the ventilation air and is exhausted from the ventilation shaft at a low concentration. Due to safety regulations, the CH_4 concentration is likely to be <0.8 percent in most instances.

Virgin Coal Bed Methane (VCBM): CH_4 rich gas recovered from coal seams which have not been disturbed by mining and which are not likely to be mined in the foreseeable future. This term is used to differentiate between surface CBM operations related to mining (CBM) and surface operations to produce gas for energy totally independent of coal mining, comparable to, in principle, with natural gas production.

Executive Summary

Introduction

The Government of China is planning to increase significantly the development and use of CBM and CMM to meet the growing demand for primary energy sources, contribute to improve the safety of mining operations and help to achieve significant reductions in China's GHG emissions.

China is short of clean energy, particularly conventional natural gas. The proven per capital natural gas reserve is only 1/12th of the world average. However, China has large CBM resources with development potential which can be recovered from surface boreholes independent of mining and in advance of mining (CBM), and also captured as a part of underground coal mining operations (CMM). However, in order to meet its targets, the government must improve the administrative framework for CBM resource management, introduce more effective CBM/CMM development incentives, raise the technical capacity of the mining sector, expand gas pipeline infrastructure and promote gas markets in coal mining areas.

Most of the world's production of CBM estimated at 60 Billion Cubic Meter (10) (Bm^3)/year is in the United States with lesser volumes produced in Australia, where gas prices are weaker, and rapid growth forecast for Canada to satisfy the U.S. market. A unique combination of favorable geology, a mature gas market, strong demand, good prices and well-developed pipeline infrastructure makes the United States an exceptional case which is not mirrored in any other country. None of the other large coal-producing countries of China, Russia, India and South Africa have established significant CBM production because of geological, technology, infrastructure and investment barriers. Low financial margins compared with conventional natural gas sources, preclude major commercial attention to CBM until strategic resources are in decline. In such cases, governments have provided specific incentives to stimulate development as in the United States and Australia.

China's CMM emissions are immense and are increasing. In 2004, the impact of China's coal output was the release of an estimated 18 Bm^3 of CH_4 (271 Mt CO_2 equivalent), almost 38 percent of China's emissions of anthropogenic CH_4. Its CMM emissions represent 43 percent of global CH_4 released by coal mining and will rise to more than 50 percent by 2020. The scale of the CMM problem facing China far exceeds that of the United States, the world's second largest coal producer after China. The U.S. underground longwall production is only 14 percent of China's 10 percent in terms of numbers of gassy mines, and vented CMM amounts to 25 percent of that in China.

Total amounts of CMM released will increase by more than 65 percent above the present level by 2020 due to inevitable rise in coal production, but the increase in the volumes vented to the atmosphere could be limited to a much lower rate by improving capture, utilization and destruction of the gas at coal mines. This is a major challenge for China which requires attention at the highest level of government, otherwise, the sustainability of the energy sector will be undermined.

Despite installing gas drainage systems in most of the large gassy mines, and constructing more than 60 CMM utilization projects in the last decade, only about 10 percent of the total CH_4 released from coal mines in China in 2004 was captured. Of the total CMM released, only 4.3 percent was utilized and the emissions thus avoided. Coal mines are draining increasing volumes of CMM from underground, but utilization of the gas is not increasing at the same rate. Most of the CMM of usable quality is already being exploited as a large, and probably increasing proportion of drained CH_4 is of too low a quality to use safely and is vented. CMM which is drained and surplus to use is also vented as flaring is not actively encouraged by the government in contrast to New South Wales, Australia, where a more stringent environmental protection regime has been established and venting of drained gas is not permitted and must be flared.

There are large numbers of mines in China which release CH_4 into the ventilation air but where gas quantities are insufficient to justify installation and operation of CH_4 drainage systems. In 2004, 15 Mt CO_2 equivalent of unused drained CH_4 was vented into the atmosphere in China together with a massive 244 Mt CO_2 equivalent of CH_4 exhausted at low concentration in Ventilation Air Methane (VAM) in 2004. VAM emissions will rise to 271 Mt CO_2 by 2010 unless action is taken to capture and use more gas and also to tackle the problem of removing CH_4 from ventilation air.

Government aims and targets

The government has shown its strong commitment to CBM and CMM development and utilization by identifying them as a priority in China's Eleventh Five-Year Energy Development Plan (2005-10).

However, no new, specific implementation measures have been introduced. Financial and fiscal policies previously introduced to encourage development and utilization of CBM and CMM, have had limited impact as is evident from the slow progress.

Enhancing control and utilization of CMM is the cornerstone of the central government's strategy to improve coal mine safety and an interministerial coordination and guidance group has been established to set objectives and provide oversight.

Ambitious targets for CMM drainage quantities, drainage efficiency and utilization have been set. By 2010, capture efficiency should reach 50 percent, the CH_4 extraction volume 10 Bm^3 and the total gas utilization in China should exceed 5 Bm^3. Achieving these targets will be challenging. For example, major government programs to improve the environmental performance of the coal mining sector in the United States resulted in whole mine gas drainage efficiencies increasing from 32 percent in 1990 to 42 percent in 2003. However, with the support of government and international agencies, implementation of new policies, investment in new technologies, and setting emission reduction as the primary goal, the target for utilization, including destruction of CH_4, will be approachable by 2010, but failure to act will limit the potentially usable CMM to just over 1 Bm^3.

The government is committed to reducing GHG emissions, including CMM, and fully supports the Clean Development Mechanism (CDM) process, but has yet to develop detailed climate change policy.

At present, there is no reliable sectorwide inventory of CMM emissions, there is no incentive to encourage large-scale use and destruction of CMM, and the effectiveness of the CDM process as a market-based instrument to drive change is being limited by government rules which do not allow revenue-sharing and participation of Joint Ventures (JVs) with foreign majority ownership.

The government recognizes the potential importance of CBM as a valuable energy resource and has set ambitious development targets.

The aim was to produce 3-4 Bm^3/year by 2005 increasing to 10 Bm^3 by 2010 and doubling by 2015, but these projections were too optimistic due to the vast drilling resource which would have been required and the limited number of favorable sites. By 2010, about 1.8 Bm^3 could be produced annually and success with Surface To In-Seam (drilling) (STIS) technologies could perhaps increase this to 3.6 Bm^3 or more. A high proportion of the surface CBM production in China in 2010 will probably be concentrated within Shanxi province where the geological conditions appear to be among the most favorable in China; there are large CBM resources and provincial government policy is to expand its exploitation to increase clean energy supply.

Current status of CBM/CMM

The estimated CBM resources in China Tera (Trillion) Meters Cubed (10^{12}) at 300 Meter (m) -2,000 m below the surface of 31.5 (Tm^3) are comparable with the total estimated resources of 38 Tm^3 for conventional natural gas, but the economically recoverable reserves of CBM are much lower due to geological, technological, market, regulatory and institutional constraints.

Surface CBM exploration and drilling started in the early 80s in China but little success was achieved until 1996, when a pilot well field was developed as part of a United Nations Development Programme/Global Environment Fund (UNDP/GEF) capacity-building project. The government recognized the need for foreign technical assistance and founded the China United Coalbed Methane Company Limited (CUCBM) in 1995 with the sole right to form foreign cooperative CBM ventures. CUCBM subsequently attracted more than US$150 million of foreign investment, but many of the choice exploration prospects were denied to foreign JVs. Although more than 400 exploration and pilot CBM wells have been drilled since 1995, little commercial production has been achieved, current utilization projects being largely demonstration.

New drilling technologies are being introduced from the United States and Australia which will allow the exploitation of low permeability coal than could previously achieve commercial production. However, CBM development will remain slow and concentrated in only a few geologically favorable areas with market access unless the processes for obtaining rights are made more open, competitive and transparent, and the large gas resources tied into existing excessively long-term coal mining leases and are separated and released. Lessons can be learned from Australia and the United Kingdom in managing the regulatory issues and overlap with mining activities.

A large increase in the quantity of CMM drained from KSOCMs has been achieved from 100 Mm^3 in 1950 when the technology was first introduced to 1.8 Bm^3 in 2004 – possibly reaching 2.2 Bm^3 by the end of 2006. Gas utilization has also increased with some 700 Mm^3 being used in 2004. Gas availability is increasing but improvements are needed.

Nearly 206 out of 621 KSOCMs now have CMM drainage systems, but average CH_4 capture efficiencies are only 23-26 percent. Growing concerns about continuing mining accidents in China led the State Council to allocate US$265 million for expenditure in 2004 to help improve coal mine safety, particularly by installing gas drainage and gas monitoring systems, and enhancing existing systems. The potential recoverable CMM reserves have thus been increased. Installation of more gas drainage systems, enhancement of existing systems, increased mining depth, and adoption of gas drainage techniques by merged, expanded and new local community-owned and private longwall mines means the volume of CMM available for use will continue to rise over the next few years. However, poor gas drainage standards, lack of investment in CMM utilization projects and grid access difficulty by CMM-fired power generation means that too little of this gas is of usable standard or is being used, and GHG emissions from coal mines are rising annually.

Coal mines continue to emit gas after coal extraction has ceased. Abandoned Mine Methane (AMM) extraction schemes have proved a commercial success in many European countries, but no major AMM sites have been identified in China as mined out areas are generally less extensive than in Europe, and most mines flood quickly after closure. However, prior to closure of large mines in China, especially where dewatering will be continued to protect neighboring mines from water inrush risks, the potential for extraction and use of the gas should be examined.

CBM/CMM utilization

Coal in China is substantially cheaper than natural gas but great efforts are being made to reduce coal-burning in cities and introduce more clean energy to improve air quality. CBM/CMM can play an important role.

An estimated annual gas consumption of 800-900 PJ/year in China is expected to grow to 3,570 PJ by 2010. Natural gas transmission infrastructure is being developed to serve major cities, but there will be large local markets for CBM. The demand for natural gas is expected to reach 120 Bm^3 by 2010 and 200 Bm^3 by 2020. By then, the shortage in natural gas will be 40 Bm^3 and 80 Bm^3, respectively, with Russian pipeline gas unable to satisfy the shortfall. Greater use of CBM/CMM will reduce the quantity of expensive Liquefied Natural Gas (LNG) imports.

The estimated combined availability of CBM and CMM for utilization in 2010 is 5 Bm^3 equivalent to 179.5 PJ compared with a projected natural gas demand of 3,570 PJ. The expected CMM capture only represents 15 percent of the total estimated gas release from coal mines so there is substantial scope for increase. The CBM/CMM industry, therefore, has potential for scaling up and continued growth over a period of years.

CMM is used widely in some coal mining areas where it is distributed via pipelines to mining communities and neighboring cities for domestic use, some is also used in colliery boilers and for small-scale power generation. About 90 MW Electricity (MW_e) of CMM power generation equipment has been installed at KSOCM, and a further 150 MW_e is planned or under construction. Some gassy, local government and privately-owned mines are also installing gas capture and utilization systems. Nevertheless, the utilization of drained mine gas in China remains low with more than half of the total gas extracted released directly into the atmosphere.

Commercial production and exploitation of the gas extracted from surface CBM boreholes is limited to a few sites where gas is compressed and transported by truck to city consumers, used for small-scale power generation or piped a short distance to consumers. LNG is being investigated as an alternative to Compressed Natural Gas (CNG) Technology, and also gas-to-liquids chemical conversion technologies.

A lack of pipeline infrastructure, the immature gas market and the underdeveloped economy of CH_4-intensive areas are three major factors which need to be addressed in developing China's CBM and CMM utilization industry, and to attract the necessary investment.

Barriers

Improvement is hindered by institutional, legal and regulatory barriers together with technical and technology barriers.

The legal framework currently applicable to CBM and CMM exploitation is nonspecific, and is encompassed by the state's coal and mineral resources laws and petroleum production regulations. The Ministry of Land and Resources (MoLaR) is revising its minerals allocation methods and replacing them with more transparent bidding and auction procedures, but this reform has not yet extended to CBM licensing and the processes for allocating CBM exploration blocks still lack transparency and competition.

CBM and CMM management suffers from the dispersion of responsibilities between various organizations and departments after the Ministry of Coal Industry was abolished in 1998, and CBM and CMM have not featured as significant administrative issues in subsequent coal mining sector reforms. Development and use of CMM is an "encouraged" activity under the Coal Law, which is also undergoing revision.

Some transformed and consolidated Town and Village Coal Mines (TVCMs) in gassy areas are operating gas drainage systems and are planning to extend the scale of their CMM utilization. These mines have not received the same level of attention or support as KSOCM. Local investment in CMM utilization at all sizes of mines is inhibited by lack of funds in Chinese enterprises and poor access to capital markets. Bureaucracy, safety issues and market concerns deter foreign investors. Major concerns of foreign investors are the security of gas supply and the variability and often low purity of drained gas. Many schemes are too small to interest Financial Institutions (FIs). However, CDM represents a major financing opportunity and many CMM projects are being developed at coal mines, but none have yet reached the registration stage, and restrictive government rules are inhibiting its effectiveness.

Drained CH_4 concentrations in Chinese coal mines tend to be highly variable and purities of 10 percent and less are not unusual. At too many mines, drained CH_4 concentrations are below the prescribed legal safe minimum for utilization of 30 percent. The problem of maintaining CH_4 purity is a significant factor in finding CMM markets and optimizing use. Poor CH_4 quality is often traceable to use of drainage methods which do not match the mining and geological conditions and poor housekeeping underground – poor sealing of drainage boreholes from air ingress, inadequate drilling equipment, leaking gas transport infrastructure in the mine, a lack of technical knowledge of gas emission and control processes and ineffective management. Some KSOCMs are looking for methods for utilizing low concentration gas rather than addressing the inadequacies of their drainage systems. Such a response is counter productive to the improvement of mine safety and to the maximization of CH_4 capture and utilization.

Recommendations

In order to significantly reduce CH_4 emission from coal mines and better exploit the gas recoverable from coal seams, the government should introduce measures (summarized in Table 1) to:

- Strengthen the CBM/CMM policy, legal and regulatory framework to improve resource management;
- Improve CMM availability and quality so more can be utilized;
- Enhance incentives to promote expansion of CBM/CMM exploitation and destruction of surplus drained CMM; and
- Promote development of regional development strategies to take advantage of specific local advantages.

Table 1: Summary of Recommended Strategy and Actions

<table>
<tr>
<td rowspan="4">China's Problems

• Major emitter of CMM
• Serious mine safety problems
• Shortage of clean energy to replace polluting coal in cities

Facts

• China released 18 Bm³ (estimate) of CMM in 2004
• 10% of total was captured by CH_4 drainage in mines for safety reasons
• 4.3% of total used for energy
• China will emit 50% of global CH_4 from coal mining by 2020 (65% increase from 2004)
• China has large CBM resources which could be exploited to reduce dependence on coal, but development is slow

China's CBM/CMM Achievements

• Introduced CMM drainage in 1950
• Drained CMM increased 100 Mm^3 to 1,800 Mm^3 from 1950-2004
• Some 50% of large mines are gassy and have gas drainage systems</td>
<td colspan="4">Strategic Response
CMM: Reduction of CMM emissions a priority with energy production optimized from use of CMM and destruction of methane maximized by flaring surplus gas financed and driven by the CDM and additional incentives. Increased capture, use and destruction of CH_4 will automatically result in safer mining conditions.
CBM: Strengthen CBM resource management under a gas and petroleum licensing regime with open and competitive bidding for license areas</td>
</tr>
<tr>
<td>Current Status</td>
<td>Areas to be Addressed</td>
<td>Actions to Promote CMM Capture, Use and Destruction</td>
<td>Actions to Promote CBM Extraction and Use</td>
</tr>
<tr>
<td>• Uncertain CMM resource due to lack of inventory
• CDM barriers
• CUCBM monopoly on JVs with foreign CBM developers hindering investment in CBM</td>
<td>Policy, legal and regulatory framework</td>
<td>• Policies and incentives to optimize energy use and maximize CMM destruction
• Establish CMM inventory
• Levy on CERs to offset lower mitigation cost of flaring
• Allow revenue-sharing from CERs
• Enforce mine safety standards to encourage capture of higher quality gas
• Prepare safety legislation ready for VAM use and destruction</td>
<td>• Separate CUCBM's roles of developer and regulator
• Introduce open and competitive bidding for CBM exploration blocks
• Separate coal mining and CBM licensing
• Underpin PSCs and CBM licensing with legislation including mining interaction agreements
• Allow qualified Chinese developers to form JV with foreign CBM company
• Mines with CBM interests to accept CBM license commitments or release stagnated coal areas</td>
</tr>
<tr>
<td>• Quality of CMM often too low for safe utilization</td>
<td>CMM availability and quality</td>
<td>• Improve knowledge and practice of gas control, prediction methods, gas drainage design and management
• Establish technical support for CER delivery</td>
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<tr>
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• 31.5 Tm^3 CBM resources
• >400 CBM exploration wells from 1995-2004
• > US$150 million foreign investment in CBM exploration attracted by CUCBM

Government CBM/CMM Aims and Targets
• Priority in Eleventh Five-Year Energy Plan
• Enhanced CMM capture and utilization as a route to improved mine safety
• 10 Bm^3 CH_4 captured by 2010
• 5 Bm^3 methane utilized by 2010
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<td>Actions to Promote CMM Capture, Use and Destruction</td>
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• CMM abatement certificates (long-term: part of a national GHG trading system)</td>
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<td colspan="4">Conclusions
• China's commitment to reducing GHG emissions can be advanced significantly, and at low cost, by stimulating greater use and destruction of CMM
• Government CBM/CMM utilization targets are ambitious and will not be approached unless the above measures are rapidly and effectively implemented</td>
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Government policy, legal and regulatory framework

CMM priorities and strategy should be redefined. Reduction of CMM emissions should be the highest priority focus and a strategy for maximizing CH_4 use and destruction is necessary if China is to significantly reduce GHG emissions from coal mining.

Policies aimed at reducing GHG emissions from coal mines will automatically result in improvement in safety and greater use of CMM for energy purposes provided international safety standards are a prerequisite for compliance.

Successful GHG emission reduction drivers in other countries, Australia, for example, operate in a market environment which China aspires to develop, but is still some way off from achieving. More rapid development of CBM and CMM resources can be achieved if the Government of China continues regulatory reforms and further liberalizing of energy markets.

The CDM has proved the most successful driver of CMM exploitation to date in China, but there are barriers preventing more effective implementation. For instance, Chinese enterprises are forbidden to enter into revenue-sharing agreements thus removing a powerful means of securing project investment. The incentive for project investors to provide continuing assistance throughout a project to ensure delivery of Certified Emission Reductions (CERs) is also removed. Reluctance to accept flaring of surplus and unusable CMM also narrows the applicability of CDM and is contrary to the aims of the United Nations Framework Convention on Climate Change (UNFCCC). Unless these impediments are removed, CMM emission reduction and energy recovery targets will not be achieved.

The following measures would ensure that CMM is utilized wherever practical and feasible and the surplus destroyed:

- Government strategy to minimize GHG emissions from its mines, implemented through policies which encourage maximization of use and destruction of CH_4;

- Policy incentives which encourage surplus drained gas to be flared, as is done in Australia and the United Kingdom, rather than vented to the atmosphere. Flaring is the lowest cost emission mitigation measure with an investment cost of per ton(t) CO_2 annual destruction capacity using imported equipment less than 1/5th of a modern gas engine. The cost would be much lower once locally manufactured flare units are available;

- A higher government levy on CERs generated by flaring to offset the lower mitigation cost of flaring compared with utilization to ensure flaring is a last resort;

- Fiscal incentives against equipment and construction costs for all GHG mitigation schemes; and

- Strongly enforced mine safety standards requiring drained gas to be of a specified minimum purity (>30 percent) for utilization to encourage mines to improve gas drainage standards and performance, capture more usable gas and become safer workplaces.

In order to formulate and implement effective strategy, the full scale of the problem must be determined by preparing a reliable and complete CMM emissions inventory.

The quantities of CH_4 emitted from China's coal mines are not known to any degree of accuracy (IPCC Tier 1 method) and the data are incomplete as they are based on the KSOCM which represent only about half of China's coal production. Without these data, the full potential for scale-up cannot be properly assessed and effective management of China's CMM resources and emissions established.

For example, a survey of county, village privately-owned mines in the highly gassy Jincheng mining area revealed that in producing 9.6 Mt of coal, some 332 Mm^3 of CH_4 was drained of which about 20 percent was utilized.

It is recommended that:

- An IPCC Tier 3 methodology should be developed and applied to all the KSOCM and a survey undertaken to establish reliable Tier 1 estimators for the remainder of the coal mining sector.

Safety legislation should be extended to pave the way for utilization and destruction of VAM.

VAM represents a significant emission and potential energy source as more than 70 percent of the CH_4 released from coal mines is exhausted at low concentrations. Technologies for removing and using low concentrations of CH_4 in ventilation air are being developed, but these will be costly requiring CDM support for viability and new mine safety legislation to allow for safe use or destruction of CH_4 at concentrations below the lower explosive limit. China will become a major target for CDM-financed VAM schemes once a suitable technology is proven, and this will lead to major reductions in emissions.

It is, therefore, recommended that:

- Safety legislation should be revised to allow the use and destruction of VAM, but incorporating a large factor of safety below the lower explosive limit of 5 percent CH_4 in air.

CBM remains in coal seams until extracted at a production borehole or disturbed by mining. Gas removed from coal seams ahead of mining, or in areas which are likely to be mined some time in the future, reduces the future threat to the environment but, more importantly, provide a valuable source of energy comparable to conventional natural gas. Institutional and regulatory reforms are needed to establish fair, competitive and effective CBM resource management if this clean energy is to be more effectively exploited.

CBM resource management in China involves a carve-up of potential prospective areas between the State-owned petroleum and CUCBM monopolies. Resource is managed by those with vested interests in the proceeds of development rather than by an independent government body serving the national interest. Foreign CBM developers are required to sign a Production-Sharing Contract (PSC) with CUCBM which sets out the rules, a minimum exploration expenditure and other conditions. However, PSCs are not sacrosanct and there is evidence that State-owned oil and gas companies have disregarded the "license" boundaries in their exploration programs. The PSCs have no formal legislative standing but are intended to provide an internationally recognized form of cooperative agreement and a basis for negotiation.

At present, CUCBM and other State-Owned Enterprises (SOEs) with CBM exploration interests (for example, Petrochina) apply to MoLaR for CBM exploration and development licenses which are issued on a first come, first served basis, unless the area is reserved for other purposes. CUCBM can decide whether to explore alone or to form a cooperative venture with a foreign company under a PSC. The current licensing system does not allow for any market competition, licences can be easily extended and there is no incentive to expedite exploration and development. As a result, exploration is inefficient and development slow. Substantial CBM license areas have been let but not explored due to lack of resource, or ranked as of low interest by the holder. Some developers have sought to build large portfolios of license areas merely to try and impress investors, but they have neither the intention nor the resources to explore and develop. Access to both coal and large associated CH_4 resources are also sterilized by coal mine leases of 70 years or more which hinder and slow development.

The formation of CUCBM as a regulator to protect the interests of China was an essential first step in establishing a CBM industry in China and CUCBM has played an important role in managing foreign involvement and investment in CBM exploration. However, administrative and regulatory needs have now changed and it is recommended that:

- CUCBM should be divested of its monopoly privileges and allowed to operate as a commercial exploration and development entity;
- The role of CBM regulator should be passed to MoLaR or a new Energy Ministry;
- A more open, competitive and transparent bidding process for CBM blocks is introduced;
- The CBM industry should be integrated into the natural gas and petroleum industry due to overlapping interests, but leaving CMM firmly in the coal mining sector;
- An effective regulatory system should be devised for managing the interaction between CBM and coal mining interests. Australia (Queensland) has established a robust scheme which could be adapted for China;
- PSCs should be underpinned by legislation, and exploration and development license boundaries enforced. Licensing terms should be more stringent and strictly enforced. CBM license areas which do not receive the requisite exploration attention within a defined time period, not exceeding three years, should be relinquished and bids invited from qualified companies;
- The costs of holding license blocks should be increased to speed relinquishing of areas which the developer has discarded or has insufficient resources to explore;
- Any qualified Chinese company should be free to enter into a PSC agreement with a foreign company, but the terms should be subject to oversight by an independent regulatory commission; and
- Licensing of coal should be separated from the licensing of CBM rights. Mines currently with CBM interests should be required to make exploration and development commitments similar to those expected of PSC holders or relinquish title to the gas. To prevent loss of coal reserves, a legally binding interaction agreement should be introduced.

The institutional and legal framework should be rationalized and strengthened.

Both coal and mineral resources laws are currently being revised, but independent of each other. Now would be an opportune time to strengthen the legal framework of the coal mining sector and, in particular, address CBM/CMM safety and interactive issues.

CBM extracted independent of mining is a natural gas production operation. CBM reservoirs are difficult and costly to develop in relation to their production potential compared with conventional natural gas reservoirs, and government policy should be aimed at encouraging the natural gas industry to develop those marginal resources most likely to be of maximum future commercial and strategic benefit. In contrast, CMM is an unavoidable by-product of mining with serious environmental and safety impacts to be considered in addition to its energy potential.

It is, therefore, recommended that:

- The revisions of the Coal and Mineral Resources Laws are examined and compared in detail and any conflicts resolved before promulgation. In reviewing the Coal Law, efforts should be made to identify the reasons for its inadequacy in addressing safety issues, in particular underground gas drainage, and also ensure there is no conflict with government aims of promoting increased CMM extraction and utilization;

- CBM should be grouped and managed along with other difficult natural gas sources such as tight sands, which should be subject to similar incentives; and
- With central government oversight CMM should remain firmly in the mining sector under provincial control.

Improving CMM availability and quality

Capacity-building is needed to fill serious knowledge and technology gaps at coal mines.

Investment in CH_4 drainage equipment and technology without an understanding of its applicability is leading to wastage, and expected reduction in numbers and severity of accidents, and increased gas availability for utilization are not being achieved. The variable, and often low quality of drained gas, is a limitation to efficient utilization which must be tackled within the mining operations. Major technical issues which need to be addressed include poor sealing of underground gas drainage boreholes, inadequate design, monitoring and management of gas drainage systems and use of drainage methods unsuited to the geological and mining conditions.

In order to improve CMM capture and quality, coal mine staff need direct access to more detailed information, knowledge and technology relating to gas emission prediction, ventilation planning, gas drainage methods, equipment monitoring and CMM utilization and destruction options. Coal mining companies need such improved capabilities if they are to be able to assist local CMM project developers to analyze project risk and present properly detailed financial arguments to attract external investment.

Implementation of an effective emissions reduction strategy for coal mines will require application of combinations of surface CBM, underground CMM and emerging VAM utilization technologies. The choice will depend on whether site-specific characteristics and the necessary capacity-building and technology transfer can be achieved with the help of a carefully designed and managed demonstration project.

Coal mining companies are also in need of support with CDM projects to deliver CERs, but a professional service support industry does not presently exist. Without this support, CDM projects at mines will underperform substantially, the Carbon(C) assets market will lose confidence in the sector and government CMM utilization targets will be unachievable.

New, fully mechanized private and locally-owned mines in gassy areas are starting to recognize the potential benefits of CMM utilization, but this sector of the coal mining industry, which is likely to grow in importance, does not presently receive the attention it needs.

It is, therefore, recommended that:

- New fully mechanized private and locally-owned mines be included in any new CMM promotional initiative; and
- Capacity building be provided:
  - To government advisers and planners, mine designers, technical staff and mine management to help them better understand the current state-of-the-art technology, its limitations and the fundamental principles of gas drainage and control;
  - To coal mining companies so that they are able to assist local CMM project developers to analyze project risk and present properly detailed financial arguments to attract external investment;

- To professional service support companies so that they can help coal mines with CDM projects to deliver CERs; and
- By a CMM demonstration project at a selected coal mine for optimization of energy recovery and maximization of CH_4 destruction to international safety standards; the CDM or the Global Environment Fund (GEF) program should be investigated as a financing source.

Strong incentives are needed to vigorously drive change

The government should further stimulate investment in CMM utilization and destruction. Existing tax benefits in China have not been effective by themselves and CDM alone will not be sufficient to stimulate the level of investment required to achieve the government's goals. Additional incentives are needed which will encourage greater levels of both domestic and international investment in CMM utilization and destruction.

A possible route is exemplified by China's Renewable Energy (RE) Law which took effect on January 1, 2006, introducing a pricing mechanism which ensures a premium over the lowest cost clean coal option and includes a government subsidy. This incentive would be particularly cost-effective if applied to CMM, as the incremental cost of power generation using CMM is much smaller than the incremental cost of wind turbine power. A possible downside is that the feed-in tariffs might polarize CMM toward power generation when, sometimes, direct supplies of gas would be more beneficial to the local economy. However, in such instances, CDM may provide an alternative financing route which would help to balance choice of options. Surface CBM extraction connected with active mining, which results in avoidance of CH_4 emissions, should be treated as CMM insofar as incentives are concerned.

Gas abatement certificates modeled on the New South Wales scheme have attractions as part of an in-country GHG trading system, but could not be introduced until a national trading scheme was established. Nevertheless, as China's GHG emissions will continue to grow, such an approach has merit as part of a long-term strategy. A more rapid response could be achieved with grant schemes similar to those developed in Australia which have successfully encouraged demonstration of new and innovative CMM utilization technologies. Projects should be selected on merit and grants only made available for properly designed, peer reviewed projects with a high chance of success. They should not be used to subsidize ill-conceived, replicated projects by coal mining SOEs as has happened too often in the past. The government could partner with GEF to foster such a scheme.

Domestic mining companies can benefit from exercising greater corporate environmental responsibility as well as assisting the government achieve its strategic aims. Domestic coal mining companies can reduce GHG emissions without detriment to their business, especially if encouraged by market-based and grant incentives as is demonstrated in Australia where innovation, Research and Development in (R&D) CMM extraction and use are enabling increasingly effective results to be achieved thus reducing long-term business and reputation risk to major companies. Spin-off benefits which directly benefit financial performance include improved gas control at the coalface, safer working conditions, a local low cost energy supply and reduced mine operating costs.

R&D is needed to enhance understanding of the characteristics of coal seam gas reservoirs in Chinese geological conditions and to explore the use of the STIS drilling technologies developed in Australia and the United States for extracting gas from virgin coal seams with marginal permeability. These advanced STIS drilling techniques could also have a role in enhancing mine safety by improving the effectiveness of both pre- and post-gas drainage methods. Wider application of advanced gas extraction and capture technologies are essential if China is to scale up its CBM/CMM industry.

China would benefit from easier access to imported gas control technology for its mines and CMM utilization schemes. However, some foreign companies with key technologies are reluctant to enter the China market due to lack of protection of Intellectual Property Rights (IPRs), cost and risk of market entry, protracted approval procedures for underground equipment (but now being improved), competition with low-cost Chinese equipment and lack of transparency in bidding for tenders.

It is recommended that:

- CMM is treated similarly to RE in China and enjoys a similar level of subsidy, as is the case in Germany;
- Grant schemes similar to those used successfully in Australia should be introduced to encourage demonstration of new and innovative CMM utilization technologies;
- Incentives to stimulate investment in CMM extraction and utilization and CH_4 emission reductions should be aimed at coal mines of all types. In particular, financing arrangements and loan facilities should be made available through local, commercial banks to facilitate development of small-scale CMM utilization schemes by local enterprises;
- Key state-owned mines, in particular the large coal mining enterprises with international expansion aspirations, should be aware of the importance of protecting reputation with regard to environmental protection and encouraged to develop corporate policies which maximize benefits from available GHG emission reduction incentives;
- Targeted R&D of CBM and CMM extraction technology should be expanded;
- Government should create policy incentives to encourage foreign service companies and JVs with the skills and experience to introduce, adapt and exploit new and advanced CBM/CMM technologies in China; and
- Barriers to importation of key technologies should be removed by recognizing international safety testing standards for certification of underground equipment, rigorous enforcement of patent and IPR protection and ensuring transparent and competitive bidding for tenders.

Regional development strategies

An effective emissions reduction strategy must recognize regional differences. For example, development of CMM utilization projects in the coal-rich Shanxi province should be a priority and would be much more cost-effective than RE. Where such conditions exist, CBM/CMM development should be afforded special status.

CH_4 extraction and utilization from coal seams in economically underdeveloped coalfield areas will benefit local communities and provide energy for displacing use of polluting coal in local, small-scale enterprises.

Rational development of CBM requires juxtaposition of market, gas transport infrastructure and geologically favorable conditions for commercial extractions, all of which are present to some extent in Shanxi province. However, in Shanxi, as in other coal-rich provinces, there is insufficient cohesion between the planning of CBM, CMM and natural gas transportation and utilization projects.

Construction of an accessible pipeline infrastructure by the government in selected areas will stimulate exploration and development of CBM and CMM (by analogy with road construction as an economic development stimulant to isolated communities). For example, in the Raton Basin in the United States, the lack of pipeline connections stalled CBM development for more than 20 years. A system of contract carriage, which allows an operator to contract a fixed transmission capacity, whether used or not, would reduce construction risk, allow multiple party access and ensure maximum use of available capacity. Such an approach has been adopted in most countries with newly developing gas industries and it is also applied by gas transmission companies in the United States. However, the usual practice in China is to adopt common carriage** and it is not unusual for CMM pipelines to be operated well below design capacities.

It is recommended that:

- The Shanxi provincial government should develop an integrated development plan and policy framework to help it meet its aspirations of a commercial and sustainable CBM/CMM industry;

- Grant assistance is given to constructing gas distribution infrastructure in special status areas and coal-to-gas switching incentives offered to consumers, but price subsidy should be avoided as this will lead to market inefficiencies; and

- All parties should be able to compete openly for access to gas pipelines and enter into contracts for transmission capacity to reduce the exploration and development risk.

** *For common carriage pipelines, there is no contracted allocation of capacity and consumers pay a composite fee with a fixed and a variable element.*

1. CBM/CMM Resources and Emissions

CBM Resources

Estimates for world Coal Bed Methane (CBM) resources range from 100 to 260 Tera (Trillion) Meters Cubed (10^{12}) (Tm^3), of which 80 percent lie in Canada, Russia and China. The estimated CBM resources in China in bituminous and anthracite coals between depths of 300 meter and 2,000 m below the surface are around 32 Tm^3. This is comparable with the total estimated resources of about 38 Tm^3 for conventional natural gas. However, the reserves of CBM potentially economically recoverable, independent of mining, will be substantially lower than the resource due to the low permeability characteristics of many of the coalfields, surface access constraints and remoteness from markets.

None of the three countries with largest CBM resources have developed significant CBM industries independent of mining although rapid buildup in Canada is projected in response to the strong natural gas demand from the United States. Of the world's largest coal-producing countries of China, United States, India, Australia, South Africa and Russia, only the United States has a mature, commercial CBM sector – 45 Billion Cubic Meters (10^9) (Bm^3) was produced in 2003 representing 8 percent of the total U.S. natural gas production, and this is similar to the total CMM release from the world's coal mining activities. A unique combination of favorable geology, a mature gas market, strong demand, good prices and well-developed pipeline infrastructure makes the United States an exceptional case which is not mirrored in any other country. CBM is being developed in Australia, but market conditions are less favorable than the United States, and technical barriers are limiting progress in some coalfield areas. CBM exploration is gathering momentum in India but large-scale commercial production is some way off due to technical, geological, price and infrastructure barriers.

In China, about 400 surface CBM wells were drilled throughout the country from 1995 to 2004 and more than 200 in the last few years. Some 150-200 Mm^3/year of CBM is currently being produced, some utilized and the remainder flared in the South Qinshui coalfield, Shanxi province, with minor production and utilization in Fuxin, Liaoning province. The Chinese government recognizes CBM development and utilization as a priority by its inclusion in China's 11th Five-Year Energy Development Plan (2005-10). Within the next few years, a combined annual CBM and Coal Mine Methane (CMM) production of 3 to 4 Bm^3 is anticipated.

There are 13 major coal-bearing areas in China where large CMM/CBM resources are concentrated. According to the China Coal Geological Administration (CCGA), the most significant CBM resources are found in the central, eastern, western, south-western, north-western and south-eastern parts of China. However, these resources are not all readily converted into potential reserves due to technical and economic barriers to development.

Ten coal mining regions (excluding the Zhunger, Tuha and Yili basins of Xinjiang region) account for 68 percent of China's total CMM/CBM resources (Table 1.1).

By 2003, there were 56 CBM exploration areas throughout China, totaling nearly 66,000 Square Kilometer (km^2). The domestic companies involved in exploration included China United Coalbed Methane Company (CUCBM), Petrochina, Sinopec, Yanchang Oil Bureau, China Coalfield Geological Bureau and the Institute of Geological Survey (IGS). Some of these organizations are able to gather valuable CBM data while undertaking exploration tasks for government departments and, thus, gain competitive advantages. CUCBM has the monopoly right to form collaborative ventures with foreign CBM companies. The registered area of CUCBM (and its international partners) is about 40,000 km^2 accounting for 61 percent of all areas, and Petrochina holds 36 percent of all areas. In 115 CBM target exploration areas from which data are available, the average gas content is 9.8 Meters Cubed Per Metric Tonne (m^3/t), the concentration of Methane (CH_4) in the coal seam gas is 91 percent, the average (CH_4) resource density is 115 Mm^3/km^2 and the average gas saturation is 41 percent. No average coal seam permeability data are quoted.

After many years of slow progress in China, interest in surface extraction of CBM seems to be increasing. This is mainly due to increasing pressure from the government to improve gas control standards in coal mines accompanied by financial support, the need to achieve high coal outputs and the emergence of Surface To-In-Seam drilling (STIS) technologies which hold the promise of better and more cost-effective gas extraction than is achievable using vertical, hydraulically fractured wells.

CBM resources are reasonably well defined but insufficient data have been gathered to characterize production potential and allow assessment of commercial feasibility in all but a few areas. Detailed coal seam permeability data are particularly lacking and viable market scenarios are yet to be established where

Table 1.1: Major Coal-bearing Regions and Associated CBM Resources

Name	Location		CBM/CMM Resources billion m^3	Major Coal Companies
	Region	Province(s)		
Sanjiang-Mulenghe Basin	Nort-heast	Helongjiang	401	Jixi, Hegang
Pohaiwan Basin	East	Shandong, Henan Hebei	1,375	Kailuan, Fengfeng
Nanhuabei Basin	East	Jiangsu, Anhui and Henan	1,678	Huainan, Huaibei
Jinzhongnan Coalfield	Central	Shanxi	4,837	Yangquan, Jincheng
Pinle Basin	South	Jiangxi and Hunan	44	Pingxiang, Fengcheng
Xiangzhongnan	South	Hunan	18	Baisha
Ordos Basin	West	Inner Mongolia, Ningxia, Shannxi and Shanxi	11,324	Baotou

Name	Location		CBM/CMM Resources billion m^3	Major Coal Companies
	Region	Province(s)		
Sichuan Basin	South-west	Sichuan	145	Furong, Tianfu
Sichuan-Guizhou	South-west	Sichuan and Guizhou	1,121	Zhongliangshan
Liupanshui	South-west	Guizhou	1,334	Songzao
Zhunger Basin	North-west	Xinjiang	2,997	–
Tuha Basin	North-west	Xinjiang	4,647	–
Yili Basin	North-west	Xinjiang	925	–

Source: Investment Guide for CBM/CMM (China Coal Information Institute (CCII), 2004).

pipeline access is either problematic or infrastructure nonexistent. Large-scale development of CBM will automatically follow the introduction of pipeline infrastructure to which it has equal rights of access compared with conventional natural gas in areas of the most promising geological conditions; current indications are that these will mainly be concentrated in Shanxi province.

CMM resources and emissions

The gassiness of a coal mine depends on coal seam geology, seam gas contents, the method of working and rate of coal extraction. CH_4 emissions in some mines are low and can be diluted to safe concentrations by the ventilation air. Other mines which are more gassy need to employ gas drainage techniques to remove sufficient CH_4, before or after mining, to ensure the planned rate of coal extraction can be achieved without statutory CH_4 concentrations being exceeded in the mine airways.

CMM resources and reserves are thus dependent on coal mining activity but are not easily quantified due to the lack of a detailed inventory.

CMM is more critical than Virgin Coal Bed Methane (VCBM), both as a Greenhouse Gas (GHG) emission and as a potentially wasted energy source. This is because CMM is released as a consequence of mining and, if not used or destroyed, will be vented to the atmosphere. VCBM, in contrast, will remain in the coal until extracted and utilized as a clean energy source comparable to natural gas.

While the United States leads the world's commercial VCBM production, China is the largest emitter of CMM releasing 43 percent of global CH_4 associated with coal mining. The immense scale of the CMM problem in China is illustrated by comparison with the United States, the world's second largest coal producer (Table 1.2).

There are about 300 large gassy Key State-Owned Coal Mines (KSOCMs) and approximately another 600 smaller locally-, community- or privately-owned gassy mines. Average capture efficiency in the KSOCM is 23 percent and there are no data for the other gassy mines, many of which have rudimentary gas drainage systems if any, at all. Pending a survey, an overall average of 10 percent is suggested as a reasonable target even if not currently achieved. A combination of inadequate investment, design, materials, infrastructure management, monitoring and operations means that drained gas quality in all mines is often poor and substantial volumes of drained gas may be neither satisfactory nor safe to meet utilization purposes. For modeling, the usable gas is assumed to be 50 percent for gassy

KSOCM and 20 percent for other mines. On the above basis, an assessment of the current situation with regard to gas capture and use was made using a simple model and the results are shown in Table 1.3.

The predicted avoided emissions of 12 Mt CO_2e for KSOCM is close to the 11.6 Million Tons (106) (Mt) CO_2e reported as used (Table 1.8) which suggests that most the of CMM of usable quality is already being exploited. Increased use will require an improvement in gas quality, or force implementation of utilization technologies which are able to exploit hazardous gas concentrations – an undesirable direction.

CMM resources are directly related to coal mining activities. Reserves depend on how much of the gas from the seams disturbed by mining can be economically captured. The average total drainage efficiency (of gassy KSOCM) is low, about 23 percent at present, but the industry believes that with further investment a drainage capture efficiency of 50 percent could be attained using existing technology and equipment. Gas drainage and utilization data are gathered annually by the State Administration of Work Safety (SAWS), but the detailed information is not published.

Growing concerns about continuing mining accidents in China led the State Council to

Table 1.2: Comparison of CMM Scale between China and the U.S. in 2004

	China[3]	USA[4]
Underground Coal Production (Mt)	1,858	367
Longwall Coal Production (Mt)	1,341	190
Net CMM Vented[1] (Mt CO_2 equivalent) including VAM	259	62
CMM Drainage Efficiency[2] (%)	23	42
% Drained Gas Used	37	90

Source: Compiled based on: China Coal Statistical Year Book Coal Production in the United States, Energy Information Administration, October 2006 from www.eia.doe.gov/cneaf/coal/page/coal_production_review.pdf.

[1] Net CMM vented means the total CH_4 released by mining operations, including the amount captured and not used, as well as the VAM.

[2] Drainage efficiency is the total amount drained relative to the total amount released in those mines which have a drainage system, and for China refers only to the KSOCM.

[3] 95 percent of total production from underground and an estimated 72 percent longwall.

[4] Scaled from results of a 2003 survey.

Table 1.3: Assessment of CMM Extraction and Usability from Gassy Mines in 2004

Type of Gassy Coal Mines	Total CMM Released Mm^3	Present Capture Efficiency %	Usable Gas %	CMM Drained and Usable Mm^3	Avoidable Emissions Mt CO_2e
KSOCM	6,915	23	50	795	12.0
Other	7,755	10	20	155	2.3
Total	14,670			950	14.3

Source: CCII.

allocate US$265 million for expenditure in 2004 to help improve coal mine safety, mainly by installing gas drainage and gas monitoring systems, and enhancing existing systems. Thus, the technically recoverable CMM reserves have been increased.

The coal sector in China has undergone substantial reform to improve efficiency, safety and price stability. Large numbers of small illegal and irrational mines have been closed and returns-to-scale are being achieved by larger mining enterprises formed by merger and acquisition. Initial estimations indicate that CMM emissions could have increased by more than 1 Bm^3 as a result of replacing small mine capacity with industrial-scale longwall operations, and also from small mines changing to longwall methods to comply with government guidance on coal resource protection measures. The increase is due to the greater extent of strata disturbance and, hence, gas release around a longwall compared with the room-and-pillar method employed in most small mines.

CMM drainage technologies only capture a proportion of the gas released into mine workings. Captures achieved in individual longwall mining panels can typically range from 30 to 80 percent depending on the drainage technology used, the geology and the mining conditions. Technologies also exist for removing the diluted CH_4 from mine Ventilation Air Methane (VAM) but are costly and only feasible with Carbon (C) financing. The potentially drainable CMM resource in China achievable using tried and tested technology is currently so large that treatment of mine ventilation air has not yet attracted much attention. However, this situation could change rapidly in the light of technological developments and the availability of CDM financing.

The total quantity of gas extracted from the KSOCM has increased substantially over the last 20 years. By 1980, there were five mining groups draining gas each extracting 10 Mm^3 per year. By 1990, this had increased to 10 groups and, by the year 2000, some 20 were practicing gas drainage (Annex I). Total mine gas extraction in 2001 was reported as 980 Mm^3, an increase of 6.8 percent from 2000 with figures for 2002 showing a further increase to 1.1 Bm^3. Consolidation of mining groups and restricted availability of recent data make continuing detailed year-to-year comparisons difficult. Table 1.4 shows CMM extraction volumes in 2003 achieved by some major mining groups but the list is incomplete.

The overall volumes of CMM drained and coal produced annually from KSOCM in the period 1997 to 2004 are shown in Table 1.5. CMM capture relative to coal production only started to increase from 2003. Annual quantities of CH_4 extraction in both the Fushun and Yangquan coal mining areas exceed 100 Mm^3, and the extraction quantities of CMM in Jincheng, Huainan and Panjiang are increasing rapidly. Projections based on the first half year for 2006 indicate a possible 2.2 Bm^3 drained by year end. No data for 2005 were available.

The government policy is to encourage mining enterprises to combine into large, efficient and competitive super groups and this is concentrating both coal production and CMM extraction into fewer organizational units, increasing opportunities for achieving-returns-to scale.

There are more than 20,000 small coal mines in China, each with coal production capacities ranging from 20-600 Thousand Tons Per Annum (ktpa) producing almost half of China's coal output. Ownership includes many local State-Owned Coal Mines (SOCMs), Town and Village Coal Mines (TVCMs) and private mines. Statistics on "small coal mine" activities are unreliable but as many as one-third are thought to be gassy. Installation of more gas drainage systems, enhancement to existing systems and adoption of gas drainage techniques by some merged and new local community-owned and private longwall mines means the volume of CMM available for

Table 1.4: CMM Extraction in 2003 by Major Mining Groups

Coal Mining Group	CMM Extraction (Mm^3)
Yangquan	252
Huainan	134
Fushun	112
Songzao	100
Pangjiang	90
Shuicheng	81
Jingcheng	74
Tiefa	74
Huaibei	55
Shitanjing (Ningmei)	51
Furong	48
Pingdingshan	34
Shenyang	32
Hebi	27
Tongchuan	25
Zhongliang	23
Liaoyuan	21
Tianfu	19
Jiaozu	18
Total	**1,270**

Source: CCII prepared for this study.

Table 1.5: CMM Drained and Coal Produced from all KSOCM (1997-2004)

Year	CMM Drainage (Bm^3)	Coal Production (Mt)	CMM Drained/Coal Production m^3/t
1997	0.76	467	1.63
1998	0.74	500	1.48
1999	0.79	470	1.68
2000	0.87	536	1.62
2001	0.98	618	1.59
2002	1.15	712	1.62
2003	1.52	830	1.83
2004	1.93	920	2.10

Source: Compiled for this study.

use will continue to rise over the next few years. Government policy is pushing small mines to change from partial extraction to longwall caving methods of mining to increase the proportion of the reserves extracted as a resource protection measure. A result will be increased emissions and more mines will need to install gas drainage systems in order to qualify for their mining licenses.

A survey of small coal mines in the Jincheng mining area revealed that virtually all practice gas drainage. The highly gas anthracite coal lends itself to predrainage without which the coal would be unworkable. In producing 9.6 Mt of coal, some 332 Mm^3 of CH_4 was drained and about 67 Mm^3 (20 percent) used for domestic supply, heating at the mine and power generation. These statistics are not generally included in the national figures. However, as this is arguably the most gassy coalfield area in China, the results should not be extrapolated to estimate national emissions associated with the medium- and small-scale coal mines.

A large contributor to China's GHG emissions

In October 2004, China completed the Initial National Communication on Climate Change, publicizing the estimated national 1994 inventories of anthropogenic emissions by sources and removals by sinks of GHGs. In Carbon Dioxide (CO_2) equivalent terms, China's total GHG emissions in 1994 were 3,650 Mt with CO_2, CH_4 and Nitrous Oxide (N_2O) contributing to 73.1 percent, 19.7 percent and 7.2 percent respectively (NCCCC, 2004:3). China's ranking as a GHG emitter in world terms in 2000 is shown in Table 1.6.

The impact of China's coal output in 2004 was the release of an estimated 18 Bm^3 of CH_4 (271 Mt CO_2e), almost 38 percent of China's emissions of anthropogenic CH_4. Approximately, 10 percent of the total CH_4 released was captured in mine gas drainage systems and only 4.3 percent was utilized and the emissions thus avoided. Fifteen Mt CO_2 equivalent of unused drained CH_4 was vented to the atmosphere together with a massive 244 Mt CO_2 equivalent of CH_4 exhausted at low concentration in VAM.

A growing problem

Since initiating economic liberalization in 1979, China has become one of the fastest growing economies in the world with its Gross Domestic Product (GDP) increasing at an average rate of just over 9 percent per year. As part of its broader structural reforms, China has undertaken extensive efforts in economic reform, energy efficiency improvement, Renewable Energy (RE) development, forestation and slowing population growth thus mitigating some of the potential GHG emission growth.

Table 1.6: China's Estimated GHG Emissions in 2000

Gases	Mt CO_2e	Rank	Percent of World
CO_2	3,476	3	14.5%
CH_4	779	1	13.2%
N_2O	645	1	19.1%
PFC	5	7	5.4%
HFC	37	2	16.2%
SF_6	3	4	7.8%
Total	**4,945**	**2**	**14.7%**

Source: World Resource Institute's Climate Analysis Indicators Tool (CAIT), 2005.

However, China remains a developing nation with the GDP per capita at only 19 percent of the world average. There are also serious imbalances among different regions and between urban and rural areas. Rural population in China accounts for 60 percent of its total. Twenty nine million poor people live with annual income less than US$77 per person. More than 20 million farmers living in border regions and remote areas have no access to electricity. Efforts to redress this imbalance, future economic growth and urbanization expansion in China will boost energy demand further, resulting in more GHG emissions unless countered with significant, additional mitigation actions in the energy sector.

China is the second largest consumer of primary energy, ranked after the United States. In 2005, the total primary energy consumption in China reached to 2,220 Million Tons Coal Equivalent (Mtce), 3.7 times its 1980 level, equivalent to the total energy consumption in EU-15 countries. The primary energy consumption mix is shown in Table 1.7.

Two-thirds of China's energy use is supplied by coal, which caused severe air pollution when burned and it consumes almost all the coal it produces. All projections show coal supplying 60 percent or more of China's primary energy in 2020. By 2020, fast growing energy consumption will pose a serious threat to environmental sustainability in China. Emissions of pollutants will exceed sustainable limits set by the government and China appears to become the world's largest emitter of CO_2, even if its per capita emissions remain relatively low compared to industrial countries.

In order to secure the energy supply and protect the environment, China is taking measures to diversify energy supply and improve the energy infrastructure. The aim is to increase the proportion of clean energy in the mix, in particular natural gas and (REs). CBM and CMM can contribute to clean energy supply but stronger incentives are needed to stimulate investment.

By 2002, energy consumption and CO_2 emission growth rate both surpassed the GDP growth rate, showing the urgency of measures needed to attain sustainable economic development. This rise is continuing unabated, in the first quarter of 2006 GDP rose at just above 10 percent and electricity consumption at 11 percent.

Recent and projected future emissions of CMM both globally and from China's coal mines are shown in Table 1.8. Most of the emission data are derived using Intergovernmental Panel on Climate Change (IPCC) Tier 1 Type estimation methods and are, therefore, inherently uncertain. However, emission avoidance is

Table 1.7: Structure of Energy Consumption in China

Year	Energy Consumption (Mtce)	Mix (%) Coal	Oil	Natural Gas	Hydropower
1980	602.75	70.2	21.1	3.1	4
1990	987.03	76.2	16.6	2.1	5.1
2000	1302.97	66.1	24.6	2.5	6.8
2003	1678.00	67.1	22.7	2.8	7.4
2005	2220.00	68.7	21.2	2.8	7.3

Source: China Statistical Yearbook, 2004.

largely measurement-based and the figures are more reliable; variability in standards of measurement and data collection mean a relatively high degree of uncertainty but it is anticipated that the rigors of Clean Development Mechanism (CDM) project validation and verification at some key mines will force the necessary improvements. There is also cause for concern over the accuracy of coal production data following retrospective revision of 1999 coal output and consumption figures by the National Statistics Bureau (NSB). Reliable data are essential for effective planning and management.

The problem can be mitigated

Total amounts of CMM released will increase by more than 65 percent above the present level by 2020 due to inevitable rise in coal production, but the increase in the volumes vented to the atmosphere could be limited to a much lower rate by improving capture, utilization and destruction of the gas at coal mines.

There is a strong financial case for encouraging greater use and destruction of CMM as a priority GHG mitigation measure. The marginal cost of power generation using CMM is 30-50 percent lower than that of wind turbine power and the investment cost per Ton (t) equivalent annual CO_2 emission avoided for CMM is US$34[1] (85 percent load, net of project emissions) compared with US$277-350[2] (40 percent load) for a wind farm (Annex II). A properly designed and managed CMM scheme can provide a reliable source of energy to an established consumer, the mine itself, whereas in comparison wind power schemes are often remote and invariably diurnally and seasonally intermittent in their operation. Flaring at US$6.5 ton CO_2 equivalent annual destruction capacity (85 percent load, net of project emissions) provides the lowest cost mitigation option (Annex II) and should be introduced where CMM utilization is not feasible or pending design and construction of a suitable CMM scheme. The latter cost applies to an imported, high efficiency, low emission ground flare specifically designed for safe use at coal mines, operating at half capacity; this cost would reduce substantially with the introduction of locally manufactured flare units.

The expected demand for natural gas in the years 2010 and 2020 will reach 120 Bm^3 and 200 Bm^3 respectively. By then, the shortage in natural gas will be 40 Bm^3 and 80 Bm^3 respectively, necessitating imports to fill the gap. Cancellation of all but two Liquefied Natural Gas (LNG) terminals due to rapidly rising costs of imports means continued use of large volumes of coal and insufficient gas to meet projected demand. Greater use of CBM/CMM will reduce the demand for imports.

The environmental benefits of increased use of CMM and CBM are clear. In order to meet the planned increase in use of gas in China's cities to reduce environmental pollution, every available resource must be mobilized including CBM to supplement natural gas supplies and CMM for thermal applications where medium quality gas will suffice. Policies aiding this process will contribute to a reduction in China's GHG emissions by reducing CMM venting and encouraging fuel switching from coal to CBM/CMM.

[1] Based on a medium-scale CMM project in China.
[2] Includes for a relative CH_4 emission from displaced coal of $10m^3/t$.

Table 1.8: CMM Emissions and Projections – Global and China (Mt CO_2 equivalent)

Year	China Total GHG Emissions CO_2e	China Total CH_4 Mt CO_2e	World Hard Coal Output Mt	World CMM Mt CO_2e (1)	China Total Coal Output Mt	Coal Mining Emission Factor m^3/t (2)	China CMM Emissions Mt CO_2e	China CMM Drained Mt CO_2e	China Avoided CMM Emissions Mt CO_2e	China CMM Relative to Global CMM %	China CMM Relative to Total CH_4 China %	Avoided CMM Emissions (%)
1994	3,650 (5)	720 (5)	3,276 (4)	449	1230	9.2	170 (134) (10)	8.4	4.0 (12)	38	24	2.4
2000	4,946	779	3,639	499	989	9.2	137 (114 (10)	13.8	4.8	28	18	3.5
2002	4,080	643 (7)	3,837	526	1,393	9.2	193	17.3	–	37	30	-
2004	–	–	4,629	634	1,956	9.2	271	27.1	11.6	43	-	4.3
2010	–	807 (11)	5,032 (6)	690	2,500	9.5	358	62 150.6 (9) 70 (13)	16.3 (8) 75.3 (9) 54 (13)	52	44	4.6 21 (9) 15 (13)
2020	–	953 (11)	5,783 (6)	793	3,000 (3)	10.0	452	–	–	57	47	-

(1) *Estimated using 9.1m³/t as a global estimator (IPCC Tier 1 method); assuming coal production 42 percent surface, 58 percent underground (based on 1990 data after United States Environmental Protection Agency (USEPA) 1994 and Irving & Tailakov) applying emission factors 1 m³/t and 15 m³/t respectively.*
(2) *Based on value estimated using author's model for 2004 for mixed types of mines and assuming no small mines by 2020.*
(3) *The rounded mean of estimates provided by the Ministry of Science and Technology (MOST), Energy Research Institute (ERI) of National Development and Reform Commission (NDRC) and China Coal Industry Association (CCIA) (after Yu Zhufeng, Clean Coal Engineering & Research Centre [CCERC]) is 2.68 Billion tons (Bt) and the latest estimation by CCIA is 3 Bt.*
(4) *Initial total combined hard coal and lignite value reduced by nominal 890 Mt to correct for lignite.*
(5) *NCCCC (2004): Initial National Communication on Climate Change of China, October 2004.*
(6) *Estimated from 2004 data assuming 1.4 percent annual growth (World Energy Investment Outlook, 2003 Insights, International Energy Agency (IEA)).*
(7) *Estimated from ratio of year 2000 data.*
(8) *Calculated as 2004 value plus anticipated CDM project reductions from fourteen mining groups totaling 7.756 Mt CO_2e assuming 60 percent of target achieved.*
(9) *Government of China target for capture of 10 Bm³ and utilization of 5 Bm³ CMM, NDRC.*
(10) *Comparative, independent estimates based on Streets et al (2001).*
(11) *After de la Chesnaye (2001).*
(12) *Estimated as 2/3 of value supplied by China Coal Information Institute(CCII).*
(13) *Best case from the analysis of feasible improvement in Table 2.6.*

Note: Dash (-) = Data not Available.

2. CBM/CMM Recovery and Utilization

CBM sources

CBM is a clean fuel with similar properties to natural gas when not diluted by air or other noncombustible mine gases. It can be recovered from coal seams by draining CMM from working coal mines, extracting Abandoned Mine Methane (AMM) from abandoned coal mines and producing CBM from unmined coal using surface boreholes. An additional term, VCBM, is sometimes introduced to represent the gas extracted from virgin coal seams using surface boreholes independent of coal mining to differentiate it from surface CBM predrainage activities associated with mines; while both rely on similar technologies, the aims are different and the difference is particularly relevant to gas extraction and utilization projects seeking CDM financing.

The characteristics of these gas sources differ in terms of reservoir definition, production technology and gas composition. The advantages and disadvantages to producers and users of the various CBM sources are compared in Table 2.1.

Table 2.1: Comparison of CBM Sources

Source	Advantages	Disadvantages
Virgin CBM surface wells (VCBM)	Consistently high gas purity obtainable (although in some geological environments the gas is CO_2-rich rather than predominantly CH_4) Operations independent of coal mining activities Improves mine safety when adjunct to coal mining operations. High turndown capability with no safety or environmental emission risk – but a potential risk of damaging well performance	Initial drilling and completion costs high Land access costs for drilling and production sites A large number of boreholes are needed together with surface collection pipework. Rugged terrain in may of China's coalfield areas makes access challenging and may limit gas recovery potential
Working coal mines (CMM)	CMM drained underground is delivered to the surface at a fixed location using existing infrastructure installed for safety reasons The gas is produced as a waste product, the primary reason for capture being mine safety	Gas purity tends to be variable and is less than 30 percent at many mines in China Potential interruption in supply can occur as linked to the mining operation, but short-term supply fluctuations can be buffered using gas holders

Source	Advantages	Disadvantages
	Utilization reduces GHG emissions by converting CH_4 into less harmful CO_2 High flow rates may be achievable	No turndown capability due to the risk of compromising safety in the mine
Abandoned coal mines (AMM)	Access to the gas reservoir is achieved using former mine entries or boreholes Reduction in GHG emissions from closed mines Can adjust supply to match demand within specified limits	Remedial work may be needed to adequately seal surface entries The accessible gas reservoir will be progressively reduced in size by rising mine water unless mine water pumping is continued No major AMM projects have yet been identified in China due to high water inflows and relatively small reservoirs

Source: Compiled for this study, information from authors.

China has rich resources of CBM. Opportunities to extract and use the gas from virgin coal seams, working coal mines and abandoned coal mines are being sought but China's experience in developing and exploiting these various resources is limited.

VCBM surface extraction in China

VCBM exploration and drilling started in the early 80s in China. Little success was achieved until 1996 when a pilot well field was developed by North China Bureau of Petroleum (NCBP), with technical assistance from the United States, in Shanxi province as part of a United Nations Development Programme/Global Environment Fund (UNDP/GEF)-supported project, Exploration for Deep Coalbed Methane.

The need for overseas assistance to accelerate VCBM development was recognized by the Government of China, and CUCBM was formed in 1995 to assist foreign cooperative ventures. In 1998, CUCBM signed the first CBM Production-Sharing Contract (PSC) with Texaco for the Huaibei mining area of Anhui province. By the end of 2001, CUCBM had signed 11 PSCs with foreign companies including Texaco, Phillips, Atlantic Richfield Company (petroleum) (ARCO), Greka, Virgin and Lowell. These contracts covered a land area of approximately 25,000 km^2 and the total CBM resources amounted to about 2 Tm^3. CUCBM recently signed the 27th PSC.

Foreign cooperative projects are favored by preferential policies and tax incentives, and some

Table 2.2: International Cooperation Projects (PSCs signed by CUCBM to 2004/5)

Block	Area km^2	Potential Resource Bm^3	Foreign Partner	Region/Province
Huaibei	2,663	60	Chevron	Anhui
Sanjiao	448	63.5		Shanxi
Sanjiaobei	1,126	55		
Shilou	3,602	175		
Linxing	3,325	300		
Fengcheng	1,541	37	Greka	Jiangxi
Liulin	198	30	Fortune	Shanxi

Block	Area km²	Potential Resource Bm³	Foreign Partner	Region/province
Zhungeer	2,817	400	Chevron	Inner Mongolia
Baode	1,079	120		Shanxi
Shenfu	3,001	600		
Hengshanbao	1,807	230	Virgin	Ningxia
Qingshui	2,317	450	Phillips	Shanxi
Shouyang	1,963	230		
Laochang, Enhong	1,072	140	Far East	Yunnan
Qinyuan	3,665	550	Greka	Shanxi
Panxie	584	20		Anhui
N Shizhuang	375	75		
S Shizhuang	455	90		
Jincheng	151	28	Sino-American	
Huangshi	305	–	Gladstone	Hubei
Baotian-Qingshan	947	160	Asia Canada	Guizhou
Total	**33,134**	**3,814**		

Source: Modified from Investment Guide for CBM/CMM, CCII with new data from authors.

US$150 million has been invested in exploration blocks covering a total area of more than 33,000 km². The present situation is summarized in Table 2.2. CBM exploration activities in the license blocks are not fully reflected in the list as some license holders have involved others through "farm-in" agreements to spread risk and increase exploration resources.

By the end of 1999, 201 CBM wells had been drilled, mostly in existing coal mining, areas but results were often disappointing and development progress was slow. Reasons for slow progress included lack of geological data to aid site selection, time taken to build experience of Chinese coalfield conditions, lack of CBM capacity within drilling and service companies and administrative difficulties. Lackluster results were partly due to low permeability in some of the explored areas and partly due to inappropriate completion methods. Test wells were generally completed by hydro-fracturing ("fraccing"), a long-established oilfield technology However inadequately designed "fracs" and the use of additives which damaged the natural coal permeability led to some wells underperforming. Additionally, there are many instances where the wells were not left on line to produce long enough to truly evaluate the production, protocols for production testing are nonexistent and many project operators have been reluctant to perform long-term tests for fear of wasting the gas.

STIS (drilling) is being evaluated at a number of locations in Shanxi province as an alternative to "fracced" vertical CBM wells and is showing promise. This technology is discussed in more detail in Annex III.

Surface CBM developments in Shanxi province

Surface CBM development is progressing in Shanxi more than in other provinces. By the end of 2004, seven foreign companies were involved in VCBM exploration, 13 PSCs covered tracts of 13,000 km^2, 122 boreholes had been planned or were being drilled and 36 boreholes were completed in 2004. Nearly 146 Kilometer (km) of seismic was shot and foreign investment amounted to US$16 million. The Panzhuang CBM project, involving cooperation between a U.S. partner, Jincheng Mining Group (JMG), and CUCBM, has installed 30 CBM wells. A domestic VCBM demonstration project in Qinshui basin, managed by CUCBM, has been approved and developed for the 100 well field at a total investment cost of 345 million yuan (Y) (US$43 million) with 50 million yuan (US$6 million) coming from the National Development and Reform Commission (NDRC). An annual gas production of 100 Mm^3 is expected.

JMC has drilled 170 surface vertical CBM wells (110 in Sihe East and 60 in Sihe West). Some of this gas is collected and compressed and sold as vehicle fuel Compressed National Gas (CNG), in Jincheng and Zhengzhou and the remainder is flared. Future plans are to blend the CBM with CMM gathered from surrounding mines to provide a reliable city gas supply to Jincheng and other cities.

The Qinnan area with its assessed reserves of 75 Bm^3 will be a center of intensive CBM development with a projected annual production of 200 Mm^3 by the end of 2005 and 3 Bm^3 by the end of 2010.

Advances are being supported by importing advanced technology. In 2004, the first STIS multibranch well was completed at the Sino-U.S. Daning coal mine and achieved a daily production of 20,000 Cubic Meter (m^3). Enhanced Coal Bed Methane (CUCBM) and the Canadian Government are cooperating in an ECBM (Annex III) project in Qinshui.

CUCBM has recently accelerated its drilling program and is establishing a rapidly rising production capacity, but it is not being matched by sales, market development being considered a secondary issue as CUCBM views itself as an exploration rather than a development company.

CMM extraction in China

CH_4 is released from coal seams which are disturbed by mining activities. As coal production increases, more gas is released. There is a limiting coal production at which the gas emitted into the mine roadways can no longer be diluted to a safe and legally acceptable concentration. In order to achieve higher coal production, some of the gas must be intercepted before it can enter the mine airways. This is achieved using CH_4 drainage techniques. Gas drainage in gassy working mines is an important safety measure as well as a potentially major source of clean fuel. These two aspects are intimately linked and both have a high profile in China due to an unacceptably high number of gas explosions and because of an urgent need to reduce GHG emission from coal mines. Serious explosions have occurred in over 45 KSOCMs. CMM drainage was started in China's coal mines in the 50s and the annual volume of CH_4 drained has risen from 100 Mm^3 in 1950 to 1.8 Bm^3 in 2004 in the KSOCM. A range of underground gas drainage methods has been developed involving both drainage before (predrainage) and after (postdrainage) mining. Predrained gas flows from underground in-seam boreholes at many mines are often low due to the low permeability characteristic of seams in many of China's coalfields. Once seams are disturbed by mining activity, permeability is no longer an issue and a substantial volume of CMM is obtained from draining gas released from coal seams disturbed by mining (postdrainage). The postdrainage methods most commonly employed are cross-measures drilling, construction of drainage galleries above long-wall panels and goaf drainage (using a pipe laid across the face start line from a cross-cut). Details of the current status of CMM drainage in China are provided in Annex III.

More than 95 percent of the coal mined in China comes from underground workings of which 47 percent (2004) is produced from KSOCM. Some 300 of the KSOCM are classified as gassy (>10 m^3/t of gas released per ton of coal mined). Two hundred and six out of 621 KSOCMs in China have CMM extraction systems at present and the government plans to set up gas extraction systems at all the KSOCM (which appears to indicate gas will be drained even where it may not be necessary). The average CH_4 capture efficiency in KSOCM with gas drainage systems is currently only 23 to 26 percent. An increasing number of the small and medium local mines are installing gas drainage systems, but the CMM quantities drained and used are not included in the national statistics and capture performance is thought to be generally low.

More than 30 percent of all China's coal mines exhibit high gas emissions. China has 911 coal mines with high gas emissions and 896 gas safety monitoring and control systems had been installed by the end of September 2005. By the end of August 2005, all the gassy KSOCM had installed safety monitoring and control systems. Of the 121 coal mining groups/bureaus, 66 are linked to a national monitoring network. China has 42 coal production counties linked to the national network and 24 counties that have a partial network link.

China's 4,462 high gas coal mines have established 4,325 gas monitoring and control systems. There are 20,213 low-gas coal mines with 7,569 gas monitoring and control systems. This large undertaking and expenditure has not resulted in any significant reduction in serious gas explosions.

CMM comprises CH_4 diluted with various proportions of air, N (deoxygenated air) and CO_2. The purity of CMM differs from mine to mine depending on geology, the mining method, the drainage methods in use, gas extraction rates, practices at the mine and the prevailing meteorological conditions. CH_4 concentrations from 7 percent to 90 percent of the drained gas have been observed at various mines. The low purity drained flows are generally a sign of incorrect choice of drainage method or inadequate design, installation or system management.

AMM extraction in China

The potential benefits of AMM extraction and utilization schemes in China include employment opportunities after colliery closure, clean energy from a waste product and a reduction in GHG emissions. There are no major schemes at present in China.

AMM schemes have proved a commercial success in many European countries including the Czech Republic, France, Germany and the United Kingdom. However, there are differences in China – fewer seams worked in the stratigraphic sequence, the mines are generally wetter and flood quickly after abandonment, the closure process is protracted, the export of electricity from small-scale power generation can be problematic, different methods of coal working are employed and workings associated with a particular shaft or drift tend to be less extensive.

Large coal mines in China invariably remain open for a considerable period even after full coal production ceases for various reasons including salvage of equipment, mining of main roadway pillars, continuing dewatering to protect neighboring mines and to maintain employment as long as possible. During the closure period the mine is ventilated, some gas drainage of sealed goaf areas may be practiced and significant volumes of GHGs can be vented. At one site, an estimated 420 Mm^3 per year of

CH_4 was emitted in the ventilation air from a closed working where the main coal production had ceased three years previously and still no sealing was planned. The U.K. government's Department of Trade and Industry (DTI) and the Foreign and Commonwealth office have sponsored projects in China to transfer AMM planning and production technology and to build capacity in AMM expertise in China. Initial surveys indicate that the scope for stand-alone AMM utilization schemes are relatively few at present but that reservoir capacity in sealed-off and abandoned workings linked to active mines may represent a resource which could be used to help meet peak CMM demand, and one small scheme has been developed. Coal mining groups are likely to have little time available for examining the potential of AMM until the safety issues afflicting working mines have been successfully tackled. AMM is, therefore, not a major issue at present and need only be considered on a site-specific basis where opportunities might arise in connection with a conventional CMM utilization scheme. However, as depths of industrial-scale mines increase and conditions become gassier, there will be opportunities in the future and the government should be aware of the potential.

Utilization of CBM and CMM

Gas utilization has also increased but at a smaller rate than gas drainage. In 2004, 1.8 Bm^3 CH_4 was reported as drained from KSOCM and an estimated 2.34 Bm^3 drained from all mines[3] corresponding to 13 percent of the total gas released. Utilization schemes at KSOCM consumed 700 Mm^3 of drained gas which can be increased, by say, 10 percent to make some allowance for likely usage in non-State mines giving an overall consumption of 770 Mm^3. The unused drained gas vented to the atmosphere amounts to 1.57 Bm^3 equivalent to almost 24 Mt CO_2. Much of this gas would have been of too low a concentration to use safely, below the minimum permitted concentration of CH_4 for utilization of 30 percent; low purity of drained gas is a major limiting factor for utilization of CMM.

The coal mining areas with the largest CMM emissions are Yangquan, Huainan, Fushun, Songzao and Panjiang. An overview of gas extraction and utilization at these and in other gassy mining areas is provided in Annex IV.

The principal coal seam gas uses in China are summarized in Table 2.3, mine-site uses in Table 2.4 and industrial applications in Table 2.5. Much of the CMM used in China is distributed via pipelines to mining communities and neighboring cities for domestic use, mainly cooking. Some CMM is used in colliery boilers and for small-scale power generation. Small-scale power

Table 2.3: Principal Uses of CBM from Different Sources in China

CBM (VCBM)	CMM	AMM
• Natural Gas Substitute • CNG, LNG • Power Generation • Chemical Conversion	• Heating and power generation at the mine site • Dedicated pipeline for domestic distribution system • Dedicated local pipeline for industrial consumers	• Supplementary supply to meet peak CMM demand (only recorded application in China due to generally poor conditions for AMM recovery)

Source: Compiled for this study.

[3] *The reported drained gas volume for KSOCM has been increased by 30 percent to allow for gas drainage in non-State mines.*

Table 2.4: Possible Mine-site Uses for CMM in China

Uses	Comments
Firing or cofiring in boilers for hot water and space heating	Common in China. Generally, only uses a small proportion of the drained gas
Coal Drying	Used in coal preparation plants in Poland, Russia and the United States. Of possible relevance to China as more coal is washed to meet increasing coal quality requirements
Shaft Heating and Cooling	Shaft heating is a mandatory process in northern China due to harsh winters to prevent ice hazards and protect miners. Shaft cooling is required in the warmer latitudes
Power Generation	Reciprocating engines, gas turbines and combined cycle plant have been used. Due to capital cost, some overseas schemes have a natural gas supply to ensure continuity of power output and, hence, revenue. Electricity surplus to mine requirements is sold to the grid
Combined Heat and Power (CHP)	Used in Poland to supply heat and power to a mine and a nearby town. Worthy of examination for China

Source: Adapted from Creedy et al (2001).

Table 2.5: Industrial Uses of CBM

Application	Comment
Burner	Process ovens, boilers – most common industrial use suitable for CBM and CMM although variable quality is sometimes a problem with CMM
Vehicles	Some CBM is used this way in China and interest is growing
Fuel Cells	Demonstrated in the United States but high capital cost. Of future interest for China once equipment costs are reduced
Chemical Feedstock, Petroleum Substitutes	Manufacture of carbon C block, formaldehyde, synthetic fuels, CH_3 OH and Di-Methyl Ether (DME). DME production is at the development stage in China

Source: Compiled for this study.

generation using low-cost domestically manufactured gas engines are proving popular at coal mines due to their flexibility. The opinion of some mining groups is that installation of power generation is less complex and less costly than gas pipeline schemes. There would be environmental advantages in using CMM in district heating boilers and Combined Heat and Power (CHP) plant in cities. These decisions should be market-driven and although the environmental advantages are clear the economics will not be favorable in all cases.

In the absence of pipelines, compression stations have been constructed to enable compressed CBM (synonymous with CNG) to be transported by truck to city consumers. More efficient transport can be facilitated using gas liquefaction technology or LNG which reduces the gas volume 600fold. While suitable for shipborne transport, application of this technology to road transport may be limited due to the gas cooling requirement, container weight and poor road conditions in many project areas. Gas-to-liquids technologies for producing Methanol (CH_3 OH) and vehicle fuels from CBM are being examined by some developers.

Gas flows supplied to CMM utilization schemes typically lie in the range or 5 to 100 Mm^3/a. The demand from domestic consumers varies widely both daily and seasonally, gas often being vented in summer. In comparison, a power generation scheme can consume gas at a steady base load rate throughout the year, offering higher returns on investment and greater reductions in GHG emissions as more gas will be used. There are relatively few CMM power generation schemes in China because local authorities and mining enterprises, for social reasons, often consider domestic consumers as a priority. Achieving an electrical grid connection is problematic in some areas. However, there is potential to develop more CMM schemes to supply power to the mines themselves as they have a predictable base electrical load and offer a number of advantages to consumers for generated power. Drained gas flow rates must be maximized to protect safety of underground operations, and, therefore, supply and utilization demand are not easily matched. Financially optimum solutions generally involve installing undercapacity utilization. Maximization of CH_4 destruction for CDM purposes might then require addition of a flare to burn surplus gas and this has been proposed at a few mine sites but rejected by the Designated National Authority (DNA).

A feature of most utilization schemes in China is that the mine forms a CMM company which accepts the gas as delivered by the mine's surface gas extraction plants and delivers it to the consumer. The management of the CMM scheme and the CH_4 drainage system are, therefore, virtually independent. A disadvantage of this arrangement is that the mine has no direct incentive to improve gas flow and quality. Possible means for motivating mines to improve drainage performance should be identified and assessed. For example, bonus payments could be offered by the CMM company to the mine based on revenue gained from sales of gas of adequate quality ($\geq$ 30 percent CH_4 concentration) supplied in excess of the contracted amounts.

By the end of 1999, more than 20 coal mining enterprises were operating some 60 CMM utilization projects. Some 90 MW_e of CMM power generation equipment has been installed at Chinese KSOCM and a further 150 MW_e is under construction including 120 MW_e by the JMG, Shanxi. Sihe mine of the JMG has laid 12 km of underground gas drainage pipe, established 16 gas extraction pumps and drilled 30 km of long, in-seam predrainage boreholes. Annual gas extraction is around 200 Mm^3 of which some is utilized in 4x400 Kilo Watt (s) (kW) gas-engine power generators and a 2x2 Mega Watt (s) (MW) power plant. Yangquan Mining Group, Shanxi province, has drilled over 120 km of underground gas drainage boreholes to recover 25-350 Mm^3 of gas per year. Gas is distributed to 120,000 households through a main distribution system consisting of three gas holders and 64 km of pipeline. By the end of 2005, Huainan Mining Group will have installed more than 24 MW_e power generation capacity and a projected 100 MW_e by 2010.

Nevertheless, the utilization of drained mine gas in China remains low with more than half of the total gas extracted released directly into the atmosphere. In developing a more sustainable, environmentally responsible coal mining industry, more effort will need to be focused on increasing the amount and quality of gas captured and the quantity used. China should continue its efforts to encourage greater international participation in mine gas utilization schemes to quicken the pace of work in this field. Large-scale development and utilization of CMM in China will help to optimize the energy structure and is of significance in ensuring a growing supply of clean energy.

CMM use is governed by the quality of the gas drained by the mine and international practice is to avoid extracting and using CMM with a composition near or within the explosive range of 5-15 percent CH_4 in air. Most countries set minimum safe CH_4 concentrations for utilization of drained gas. For example, the minimum CH_4

concentration permitted for safe utilization at working mines in the United Kingdom is 35 percent subject to suitable monitoring and control safeguards, and Australia requires judgment based on formal risk assessment.

This safety issue is not taken seriously in Chinese mines. Chinese regulations implemented by the former Ministry of Coal Industry set a 30 percent minimum concentration value, but this is interpreted by some mining groups as applicable only to CMM for domestic use and others as outdated and no longer applicable. Shengli Power Machinery Company has produced a gas-engine capable of running and generating electricity from CMM containing 6-25 percent CH_4. A proprietary water injection system protects the inlet pipe work from explosion propagation risk. Following a utilization workshop in Dongyin city, many mining groups, including Fuxin and Huainan, signed contracts to purchase this equipment. By October 2005, orders had been placed for 77 generating sets. While the technological solution to use of CMM of low purity is innovative, the safety implications are cause for concern.

To ensure safety of utilization developments, and reduce uncertainty for developers, this issue should be resolved and clear guidance issued by the government. Many gassy Chinese mines are now utilizing low concentration gas, or planning to install low CH_4 concentration gas-engines, rather than addressing the inadequacies of their drainage systems, for example, in Guizhou province. Such a response is counterproductive to the improvement of mine safety and to the development of a sustainable CMM utilization industry.

VAM represents a significant source of GHG emissions and energy as more than 70 percent of the gas released from coal mines is exhausted at low concentrations. Technologies for removing and using low concentrations of CH_4 in ventilation air are being developed to reduce the major source of GHG emissions from coal mines and also to generate heat and power. Most of these technologies will be costly, requiring CDM support for viability in most instances. Megtec System has developed a thermal oxidation device called the *Vocsidizer* capable of removing all the CH_4 from a ventilation stream and generating power. Two pilot-scale tests have been successfully completed in the United Kingdom and Australia and feasibility studies have been undertaken in Huainan. A full-scale system was to be completed in Australia by mid-2006 but has experienced delays. Although the Megtec System may not necessarily be the optimum solution, it is a commercial equipment carrying full manufacturers support and maintenance thus reducing ownership risk. Alternative, but less proven VAM technologies include specially adapted lean burn turbines and catalytic oxidation reactors developed in Australia and Canada, respectively. A feature of most VAM technologies is that additional drained gas must be added to provide sufficient energy to generate power and the implications of displacing more efficient energy recovery must be considered on a site-by-site basis. A more straightforward use of VAM could be combustion air in boilers at mine mouth power plants provided the gas can be satisfactorily cleaned.

Government plans and targets

CMM

Improving control and utilization of CMM is the cornerstone of the government strategy to enhance coal mine safety and gas drainage performance targets have been set, which will drive growth in CMM availability and utilization:

- By 2006, capture efficiency should reach 30 percent, the CH_4 extraction volume 4 Bm^3 and total gas utilization in China exceed 800 Mm^3. In mining areas with gas drainage, 50 percent of the captured gas should be used and areas not yet using gas should start to do so; and

- By 2010, capture efficiency should reach 50 percent, the CH_4 extraction volume 10 Bm^3 and the total gas utilization in China should exceed 5 Bm^3 with half of the drained gas being exploited. Gas utilization for residential and industrial purposes shall exceed 2 Bm^3 and for power generation 3 Bm^3. Installed gas power generation capacity shall exceed 1,500 MW_e with more than 50 percent in combined cycle. It is unclear whether the plan refers to CMM, CBM, natural gas or assumes a combination. For CMM projects, where there are gas supply and quality risks, it will be difficult to justify and finance costly but highly efficient, combined cycle power generation in many instances.

Capture efficiency targets are assumed to apply only to KSOCM draining gas. Combined cycle generation may allude to use of waste heat from gas-engines for driving steam turbines rather than gas turbine and steam turbine combinations.

The above targets are ambitious and largely arbitrary in that technical feasibility, financial and economic implications do not appear to have been assessed. Nevertheless, these objectives provide a reference against which CMM projects can be promoted and will strongly influence the development of CMM extraction and utilization policy. The onus for delivering these objectives will fall on the provinces with the largest and gassiest coal mining sectors, Shanxi province in particular.

CMM capture and use by 2010

Annual increases in coal production, a greater proportion of production from longwall operations and an expectation of increasing gas drainage capacities and performance will lead to increasing volumes of CMM availability. The expected CMM quantities emitted and used in 2010 (Table 2.6) have been estimated assuming from 2004 to 2010 the proportion of coal extraction using longwall methods increases from 40 to 80 percent in KSOCM, and from 20 percent to 40 percent in TVCM, thus increasing the overall average specific emission factor from 9.2 to 9.5 m^3/t.

The predicted emissions reduction of about 18 Mt CO_{2e} for the scenario of no improvement in CMM drainage performance (Table 2.6) corresponds fairly closely to the 16 Mt CO_{2e} value predicted by adding expected reductions from CDM for CMM projects to the 2004 figure (Table 1.8). It is important to recognize that Table 5.1 only refers to gassy mines as these are the

Table 2.6: CMM Extraction and Usability Scenarios for Gassy Mines in 2010

Type of Gassy Coal Mines	Total CMM Released from Gassy Mines Mm^3	Gas Used if no Improvement over 2004 Standards Mm^3 (1)	Gas Used if Improved Standards Mm^3 (2)	Gas Used if Improved Standards Plus Use of VAM Technology Mm^3 (3)
KSOCM	8,835	1,016	2,120	2,792
Other	9,915	198	793	793
Total Mm^3	18,750	1,214	2,913	3,585
Total Mt CO_{2e}	282	18.3	43.9	54.0

Source: Compiled by authors for this study.

(1) 23 percent capture and 50 percent usability at KSOCM; 10 percent capture and 20 percent usability at others.
(2) 30 percent capture and 80 percent usability at KSOCM; 20 percent capture and 40 percent usability at others.
(3) Removal and use of 10 percent of the total vented (unusable drained gas and ventilation air) at KSOCM only.

locations where lowest cost reductions can be achieved. The CMM emissions from the remaining mines will be exhausted to atmosphere at very low concentrations, too costly to remove in any significant quantity. A combination of improved CMM drainage system design and management, more conventional utilization supplemented by flaring, together with implementation of VAM technology at some key sites has the potential to reduce CMM emissions at coal mines by 3.6 Bm^3 or 54 Mt CO_2 equivalent in 2010, most of which will be recovered as useful energy. The best CMM emission reduction which could reasonably be achieved is 15 percent of the total, well below the government target which equates to 21 percent (Table 1.8), or 5 Bm^3 CH_4.

Examination of CMM capture and utilization potential on the basis of mine-type reveals that there is less scope than previously thought for increased use and mitigation of CMM emissions. Blanket application of an average 30 percent capture, for instance, across all coal mines does not take account of the large number of mines which vent gas but where quantities are insufficient to justify installation and operation of CH_4 drainage systems.

Future CBM availability

CBM development has not advanced in China as originally planned by the government. The aim was to produce 3 to 4 Bm^3 a year by 2005, increasing to 10 Bm^3 by 2010 and attaining 20 Bm^3 by 2015. These projections may be too optimistic. If the average borehole gas flow was, say 3,000 m^3/day (a generous figure for a national average), then some 2,700 production boreholes would need to have been completed by 2005 and 18,200 by 2015. If, in addition allowances, were made for exploration, poor producers and replacement boreholes, substantially more drilling would have been needed.

CBM production from surface wells is, therefore, difficult to project for 2010 with any degree of certainty and the following very broad assumptions have been made: 400 boreholes are installed per year for four years to 2010, the conservatively average flow is 3,000 m^3/day and infrastructure exists, which allows all the gas to be sold. The estimated production is about 1.8 Bm^3. Wide use and success with STIS (drilling) could raise the average gas production substantially; perhaps even double it to 3.6 Bm^3 which is close to the value projected for Shanxi by its provincial government. Although there are many instances where the application of directional drilling may be warranted, it is highly dependent on the geological structure and properties of the reservoir and commercial success will ultimately depend on the economics of each case. In any event, it is probable that a high proportion of the surface CBM production in China in 2010 will be achieved within Shanxi province.

The estimated combined availability of surface CBM and CMM for utilization in 2010 will be in the range of 3.0-7.2 Bm^3 depending on the degree and effectiveness of policy support. The average value is close to the NDRC target for CMM use alone of 5 Bm^3. There is, therefore, considerable scope for scaling up the CBM/CMM industry. However, the magnitude of the scale which should be targeted is uncertain due to incomplete data on CMM emissions, uncertainties in the quantities of CMM drained and used, and the exclusion of non key State-owned mines from the statistics which could be of increasing importance.

Shanxi provincial integrated CBM/CMM development strategy

The Shanxi provincial government has prepared a detailed review, plan and suggestions for the integrated development of CBM and CMM extraction and use within its province. Construction of CBM, CMM and natural gas transport infrastructure is included.

The estimated total CBM resource in Shanxi is 10 Tm^3 distributed mainly in the Qinshui, Hedong, Xishan, Huoxi and Ningwu coalfields. More than 80 percent of the resources are concentrated in the Qinshui (32,000 km^2 at depths of 300-600 meters) and Hedong (1,700 km^2 at depths of 400-900 meters) coalfields and they constitute the main commercial development opportunity. In north-east Qinshui, total coal thickness is 15 m, CH_4 contents range from 7-18 m^3/t and CBM abundance is 280 Mm^3/km^2. In south-east Qinshui, total coal thickness is 10 meters, CG_4 contents are reported as ranging from 5-38 m^3/t (but the high value is not tenable) and CBM abundance is 170 Mm^3/km^2.

The projected annual demand in Shanxi is summarized in Table 2.7. There may be additional demand from Beijing and Tianjin as well as from the neighboring provinces of Hebei and Henan.

Pipeline transport

Three natural gas pipelines pass through Shanxi province: Shaanxi-Beijing 1 (330 km); Shaanxi-Beijing 2 (260 km); and the West-East (328 km). These will soon be at full capacity carrying natural gas from the Tarim and Ordos basins to eastern cities and, therefore, largely inaccessible for transport of virgin CBM produced in Shanxi. One natural gas pipeline, Linfen to Hejin, has been completed in Shanxi. Other internal provincial pipelines are the Jincheng-Yancheng-Zezhou CMM collection and distribution system (90 km) which is planned for construction in 2006 and the Dayu-Yuanping natural gas pipeline (90 km) which is to be commissioned by the end of 2005.

Main development issues raised in the Shanxi government report

The provincial government has firm views on what it sees as the problems:

- CBM and CMM development is uncoordinated and a unified industrial policy is required;
- Shanxi province should play a key role in the development of CBM resources;
- The rights of coal and CBM development and extraction require policy to account for and adjudicate conflicts resulting from overlapping interests;
- Joint venture CBM activity has been slow which implies possibly ineffective partners;
- The price of CBM is not reasonable leading to conflicts between suppliers and consumers; and
- Investment in CBM development has been too low.

Issues to be addressed in Shanxi

The report suggests the following actions, some of which may be considered controversial as a means of addressing current deficiencies and speeding the development of a large and sustainable CBM/CMM industry within Shanxi:

Table 2.7: Projected Annual CBM Demand in Shanxi (Based on Shanxi CBM Report, 2005)

Years	Total (Bm^3)	Civil (Bm^3)	Industrial (Bm^3)	Power (Bm^3)	Chemical (Bm^3)
2005	0.53	0.474	0.044	0.012	–
2006-2010	3.54	1.153	0.218	0.202	1.970
2011-2020	7.10	2.115	0.800	0.628	3.558

Source: See report references.

- The current CBM blocks are too large, development too slow and they should be reregistered under new terms and commitments;
- New policy is required to recognize the order and priority of rights, CBM extraction first, mining second;
- CBM administration should be devolved to provincial level (this was done previously with the KSOCM when the Ministry of Coal Industry was abolished);
- Supervision and reporting of activities should be strengthened;
- A CBM price coordination system should be established (increased government intervention in the market); and
- Policy should be introduced to encourage development of a CBM industry.

The Shanxi government views CBM as an abundant, largely untapped clean energy source for the province, and its recovery as a new technology with industrial growth potential. Benefits of its exploitation are the assistance of economic development in some poor areas, improved coal mine safety and a means of improving air quality in its polluted cities. The analysis and conclusions of the provincial government may have technical validity but may not be economically sound and are certainly not concordant with the idea of market-driven systems where rationalized energy prices are driven by parity pricing of energy equivalent products.

3. Administrative, Regulatory and Policy Framework

CBM and CMM extraction are managed under different regimes, but despite both being generally aligned with coal sector interests, regulation of interaction between them is poorly defined and existing policies to encourage exploitation of both CBM and CMM resources have been largely ineffective. The administrative, regulatory and policy framework, therefore, needs to be reviewed and strengthened if government plans to more fully utilize these resources are to be realized.

Legal framework

The legal framework currently applicable to CBM and CMM exploitation is nonspecific and is encompassed by the State's *Mineral Resources Law, the Coal Law* and the *Regulations for Registering to Explore for Mineral Resources Using Block System,* the *Regulations for Registering to Mine Mineral Resources, the Regulations for Transferring Exploration Rights and Mining Rights*. There may be overlap with petroleum regulations under which natural gas would be considered: *Regulations of People's Republic of China Concerning the Exploration of Offshore Petroleum Resources in Cooperation with Foreign Enterprises* and *Regulations of People's Republic of China Concerning the Exploration of Onshore Petroleum Resources in Cooperation with Foreign Enterprises*. The latter two regulations are applied to CBM development involving Chinese-foreign cooperation.

Both coal and mineral resources laws are currently being revised, but independent of each other. The revisions should be examined in detail before promulgation and any conflicts resolved. In reviewing the Coal Law, efforts should be made to identify the reasons for its inadequacy in addressing safety issues, in particular gas control and gas drainage.

The ownership of CBM rights has provoked controversy between coal mining and petroleum industries and licensing regimes in other countries prior to the new law being passed to clarify the issue. China should seek to forestall this future potential problem by rationalizing the present legal framework. CBM and CMM licensing regimes established elsewhere should be examined to aid this process, for example, Australia and the United Kingdom.

Administrative framework for CBM and CMM

The CBM and CMM administrative framework is not well developed and suffers from the dispersion of responsibilities between various organizations and departments after the Ministry of Coal Industry was abolished in 1998. CBM and CMM have not featured as significant administrative issues in subsequent coal mining sector reforms. CMM regulation essentially follows that of coal mining which has been the subject of a previous World Bank study (Mitsubishi Research Institute [MRI] et al. 2004) and together with CBM is now receiving special attention from central government in a new initiative to improve coal mine safety.

CBM exploration and extraction rights are licensed by the Ministry of Land and Resources (MoLaR). NDRC or Provincial Development and Reform Commission (PDRC) is responsible for project approval depending on scale, and CUCBM has the exclusive right to form Joint Ventures (JVs) with foreign CBM developers. CUCBM also assists its foreign partners submit contracts for approval by the Ministry of Commerce.

Government regulation and management of surface CBM extraction and Use

As an emerging industrial sector, the CBM industry in China is characterized by high risk. This makes it appropriate for China to adopt international cooperation in the initial stages of exploration and development. Thus, China can learn the required advanced technology in return for foreign investors participating in CBM development and utilization.

By the end of the 80s, China had begun to successfully identify and develop CBM resources. After observing the successful development of CBM in the United States, many international companies sought partnerships with China and a total of 12 international partnerships were initiated during this early phase. However, because few policies were in place to govern such partnerships, and due to conflicts between different State agencies, many problems arose.

Administrative regime

The State Council sought to resolve the administrative problem in 1995 when it established CUCBM to coordinate all phases of international partnerships for CBM exploration and development. CUCBM was awarded the monopoly right concerning CBM exploration, development and production through cooperation with foreign firms. Responsibilities included relevant tendering, negotiation, contract signing and implementation once a target block is approved by the competent State authorities. It is unclear whether CMM was included in this remit, but it is unlikely to have been the intent of the State Council to give CUCBM any jurisdiction over coal mining activities which are the responsibility of provincial governments. In any event, a CBM developer cannot proceed with exploration without obtaining an agreement with the holder of mining rights.

Where VCBM and coal mining activities are in close proximity, coal mine owners should clearly be consulted, but there is no legal framework, policy or procedures, which address the safety issues of CBM and coal mine interactions when two or more different parties are involved. Such procedures have been successfully implemented in other countries and China could learn from these examples. In China, there is no clear differential made between surface CBM activities undertaken for energy production, known as VCBM and CBM activities undertaken primarily to facilitate safe production of coal.

The formation of CUCBM as a regulator to protect the interests of China was an essential first step in establishing a CBM industry in China. However, as the industry has grown and started to mature, the regulatory needs have changed. CUCBM has become a developer in its own right in conflict with its duties as a regulator for the government and JV partner with foreign companies. The contradictory position of CUCBM is compounded by the resentment of some coal mine operators to its intervention in CBM activities in their mining leases, thus deterring partnerships between mining companies and foreigners which could be beneficial to mining and safety; conversely, some partnerships between CUCBM and foreign entities have been thwarted due to difficulties in the relationship with the mining group.

If a CBM development project designed for implementation in coal mine areas is to be implemented using foreign grants or free technical assistance, that is, if the projects are nonprofit-making and noncommercial in nature, it is not necessary for CUCBM to get involved.

Production-Sharing Contracts

CUCBM is the mandatory Chinese JV partner for foreign investment in China CBM. CUCBM is owned 50:50 by the China National Petroleum Corporation (CNPC) and the China Coal Construction Group, both State-owned enterprises. International cooperation for surface development of CBM is implemented through the mechanism of PSCs which ensures the foreign participant carries the exploration risks but is able to recoup these expenses at the development stage with the help of a package of tax incentives.

Contract terms are typically for 30 years and a sizable sign-on fee is usually required. Contracts are implemented in three phases – exploration, development and production. The contractor commits to an exploration work program and expenditure over a five-year period. Subsequent development costs are borne in proportion to ownership, with the contractor preferentially receiving cash flow until a 9 percent rate of return is realized. CUCBM's role is to facilitate local approvals and liaison with local and government bodies. A joint management committee, including CUCBM, comprises the decision–making body. The PSC requires commitment to training and technology transfer at the contractor's cost and preference for Chinese goods and services where competitive. Ownership of data is vested with CUCBM.

PSCs enjoy more preferential treatment than conventional oil and gas PSCs in terms of extended contract time, reservation time, return of blocks and the various fees and expenses paid by foreign parties; this is reasonable as there is a longer period from exploration to development and the build-up to peak production is generally slower than with oil and gas production.

The general principles embedded in CBM PSCs are summarized in Annex V. CUCBM applies two rules regarding CBM exploration, but these are not enshrined in any recognizable formal policy or law:

- To avoid infringing upon the existing coal mining company in a region, CUCBM will endeavor to exclude the coal mining area from the CBM-potential area when cooperating with international partners to develop a CBM project; and
- The coal mining company should be one of the Chinese partners in the development phase when CBM exploration is adjacent to or within the coal mining area.

Chinese CBM project developers do not need to involve CUCBM, neither do they need to involve foreigners.

Regulations regarding foreign participation in CBM & CMM projects

Specific projects call for different types of investment. A *coal bed methane exploration and development project* is intended to develop CBM resources on a large scale, using either of two investment forms: Chinese-foreign cooperation, or independent foreign investment. However, for *a coal mine methane recovery and use project,* because CMM is developed within areas where exploration and mining rights have already been obtained, foreign investors can only participate using Chinese-foreign cooperation or Chinese-foreign JV, according to the principle of exclusive exploration and mining rights outlined in Chinese law.

In China, if there are more than two kinds of mineral resources available for mining in the same region, the resources are defined as either *main mineral* or *associated mineral* in accordance with their principal and subordinate roles during exploration and development. CBM resources are regarded as the principal mineral where CBM exploration and development is conducted on a commercial scale outside the active mining areas.

The projects of this kind belong to the *coal bed methane exploration and development* category included in the *Guidance Catalog of Industries for Foreign Investment,* which can be managed according to the modes of oil and gas exploration and development.

CMM can be regarded as the associated mineral for CMM utilization projects in active mining areas where the mining license has been obtained by a coal enterprise according to law. This type of project falls into the category of *comprehensive development and utilization of low heating value fuels and coal mine associated resources included in the Guidance Catalog of Industries for Foreign Investment,* which is managed in accordance with the comprehensive utilization policies in China. The two types of projects are *encouraged* industries for foreign investment. However, they are different in terms of management method and policy.

If a foreign company wanted to invest in CMM exploitation projects and the comprehensive utilization projects of coal mine gas in active coal mines, or coal mines which are being built in China, these projects would be examined and approved according to general provisions for the investment of foreign businesses. Projects with estimated costs above the investment threshold of US$30 million should be reported to NDRC for examination and approval. Projects with a cost less than the investment threshold can be examined and approved by development and reform commissions from the province and municipality directly.

Policy and regulations on CMM drainage in China's coal mines

Government support for mine gas extraction and utilization is given in Article 35 of the Coal Law of the People's Republic of China which states that coal mine enterprises are encouraged to develop coal washing, coal preparation, comprehensive development and utilization of coal mine methane, waste coal, slime, low quality coal and peat.

The third session of the State Council Work Safety Commission (SCWSC) (2002) confirmed that safety in coal mines should focus on gas control stating that coal mines should adhere to the principle of predrainage of gas, gas monitoring and testing in the course of production and deciding on coal production rate according to secured ventilation.

China's mining laws and regulations are highly prescriptive. Conditions are specified for classifying a mine as gassy, for the introduction of gas drainage and for safe operations within the mine. The current philosophy seems to be that if a mine is classified as gassy or outburst-prone, then it should install and operate a CH_4 drainage system irrespective of technical feasibility and alternative CH_4 control options.

In February 2005, the State Council decided to establish an interministerial coordination and guidance group for CMM control to combine various efforts and take comprehensive measures to arrest the too frequent occurrence of major gas explosions in coal mines. The group is led by the NDRC, assisted by SAWS, State Administration of Coal Mine Safety (SACMS) and the Ministry of Science and Technology (MOST), with the Ministry of Finance, the Ministry of Labor and Social Security, the Ministry of National Land Resources, People's Bank of China, the State Resources Commission, the General Administration of Environmental Protection, the Chinese Academy of Engineering, National Development Bank, China Coal Industry Association (CCIA) and other departments and agencies as members. Its day to day work is carried out by the Energy Bureau of NDRC.

The group's main responsibilities are to:

- Organize and lead the national effort to control and utilize CMM;

- Prepare an overall plan for coal mine gas control and utilization;
- Organize the preparation of coal mine safety standards, technical standards, management standards and personnel qualification standards;
- Guide scientific Research and Development (R&D) in gas control and utilization;
- Develop policy measures for coal mine gas control and utilization;
- Determine priorities and financing for coal mine gas control and utilization; and
- Coordinate the implementation of plans for coal mine gas control and utilization, the construction of key pilot projects and other major issues.

The group's main tasks are to coordinate major problem-solving initiatives related to resources, technologies, equipment and qualified personnel for coal mine gas control, effectively prevent major coal mine gas accidents and, for the moment, focus mainly on CMM control and utilization. This grouping ensures policy efforts are closely coordinated and establishes NDRC as the lead decision maker but dilutes the authority of SACMS, the organization responsible for implementing and enforcing coal mine safety and overseeing technical mining matters relating to CMM extraction and use. The august steering group recognizes China's technology limitations and has introduced policies aimed at redressing this deficiency.

A National Engineering Research Center on Gas Control will be formed by Huainan Coal Group and China University of Mining Technology. Nearly 150 M Yuan will be invested in the center over a three-year period. R&D will be undertaken and a number of pilot projects will be carried out to promote comprehensive gas control and utilization. Huainan Mining Group's gas extraction and utilization projects will provide one of the first national demonstrations. Whether good international practice will be exemplified is uncertain.

International cooperation is to be strengthened through international exchange and cooperation and use made of advanced foreign technologies and management systems in order to improve gas control and utilization.

Financial and fiscal incentives for CBM/CMM

Various financial and fiscal policies have been introduced to encourage development and utilization of CBM, and CMM but it is evident from the slow development of these industries that their impact has been limited. Details of fiscal policy applicable to CBM/CMM extraction and utilization are provided in Annex VI and the salient points are discussed below.

CBM policy incentives

CBM PSCs allow for the recovery of exploration and development costs by the foreign participant before sharing of the proceeds commences. CBM price is a matter for buyers and sellers to agree and is, therefore, largely market-determined. The foreign investor also enjoys tax advantages, but these and other concessions (Table 3.1) have not provided a sufficient incentive to kick-start major investment. More effective promotion of CBM development among domestic and foreign investors therefore, requires, stronger incentives or the removal of barriers, or a combination of both.

CBM production is treated similarly to petroleum and natural gas in terms of fiscal rules which is rational, but in terms of planning and promotion it is attached to the coal mining sector in which it receives no special policy consideration other than ad hoc initiatives.

The SACMS which was formed from the former Ministry of Coal Industry has, in recent years, been charged with examining regional CBM

Table 3.1: Summary of Preferential Policies for CBM Projects

Category	Item
Enterprise Income Tax	• 30 percent and 3 percent local tax, total income tax rate is 33 percent • Tax 0 percent from first to second year, 16.5 percent from third to fifth year • Other local preferential policies • Preferential policies on depreciation calculation
Value Added Tax	5 percent
Resource Tax	0
Royalty	0 to 3 percent varies with the location and gas production
Tariffs	0 percent except those listed in the not exempted category
Exploration Right Acquisition	100 yuanY/km/yr, but can be exempt
Mining Right	100 Y/km/yr, but can be exempt
Other Tax	<1 percent vehicle and ship license tax and urban property tax

Source: Based on Investment Guide for CBM/CMM, CCII.

development prospects, for example, in Chongqing, which is outside its current role but a default role in the absence of any central authority responsible for coal mining issues.

CMM policy incentives

Preferential policies are to be formulated to promote enhanced CMM extraction under the 11th Five-Year Plan which are likely to involve tax reduction and exemption, product pricing measures and specifically encourage power generation for grid distribution. The details of these new policies and how they will address current weaknesses are yet to be announced.

Key policy measures proposed by central government will result in wider use of gas drainage and, hence, new opportunities for CMM utilization as small- and medium-sized mines upgrade through merger and transformation into more efficient and environmentally responsible industrial-scale production units. Resource protection policies which encourage all coal mines to use longwall coal mining methods to maximize coal recovery will not only lead to greater gas emissions, but also new challenges on introducing CMM capture and use at community-level coal mines. State subsidies for renovation of safety equipment, including gas extraction, will continue. Enforceable standards on gas extraction before coal mining are to be formulated, but if these are too prescriptive, they will be counter productive. A combination of surface and underground gas extraction has been identified as an important gas control strategy, but to be effective, this approach should include a methodology for ensuring selection of suitable technologies, performance specifications and guidance on how to achieve them.

CMM extraction in KSOCM currently receives financial support from the government and is a legal requirement at gassy mines for obtaining a mining license. Having extracted the gas, there are fiscal policies to encourage foreign investment (Table 3.2) but no policy incentives to encourage large-scale development of the resource or to maximize destruction of the CH_4.

The policies applicable to encouraging use of CMM are weak and not fully implemented. Projects which qualify under the list for comprehensive utilization of resources, pay no

Table 3.2: Summary of Preferential Policies for CMM Projects

Category	Item
Enterprise Income Tax	• 30 percent and 3 percent local tax, total income tax rate is 33 percent • Tax rate is 0 percent from 1st-5th year • Other local preferential policies
Value added Tax	5 percent
Resource Tax	0
Royalty	0
Tariffs	0 percent except those listed in the not exempted category
Exploration Right Acquisition	0
Mining Right	0
Other Tax	<1 percent vehicle and ship license tax and urban property tax

Source: Based on Investment Guide for CBM/CMM, CCII.

income tax for the first five years from inception if an enterprise is exploiting a waste which it produced in the first instance. A coal mine implementing a CMM scheme should, therefore, be entitled to this beneficial tax treatment. If the waste produced by one company is used by another, the tax relief only applies for one year.

The preferred use of CMM in China is for heat supply and power generation. Where power generation exceeds 500 kW, the scheme is eligible for grid connection at no charge but, in practice, the connection has been resisted in some areas. Where CMM power supplies the grid, some mines are required to purchase power from the grid rather than only supply the surplus electricity. The catalog of the industries, products and technologies currently encouraged by the State for development include the use of low heating value fuels, such as CMM, and investors are exempted from import tariffs and import-linked Value Added Tax (VAT).

The CDM provides an incentive to use and destroy CH_4 but it will not be applicable at all mines due to lack of scale (to cover CDM project development and transaction costs) or noncompliance with the stringent applicability conditions. Implementation of CDM projects at mines will initially be difficult due to the need for highly organized monitoring regimes which will take time to establish. Due to concerns that energy will be wasted, the government is reluctant to encourage flaring of CMM at mines. Where there is no utilization, or where gas flows at times exceed the requirements of an existing utilization scheme, flaring could contribute significantly to emission reductions. Unless policy is developed which is more responsive to the urgent need to reduce GHG emissions, significant reductions in CMM emissions to the atmosphere will not be achieved. A policy is needed to establish priorities and encourage the most effective action including a positive climate change response.

Tax concessions under Western Regional Development policies also apply to CBM and CMM, but market access is problematic in some of these areas.

4. Barriers to CBM/CMM Development and Scale-up

The government has plans to increase CBM and CMM utilization, but implementation will require the removal of institutional, policy, regulatory, financial, information, market and technological barriers which are inhibiting investment and development.

CBM regulatory regime

The views of CBM project developers active in China were sought. Responses regarding PSC conditions among foreign CBM license holders and bidders were highly variable. A foreign partner with CUCBM can be faced with start-up and support costs in excess of US$1 million together with a cumulative exploration commitment calculated from when an exploration block was first released to CUCBM by MoLaR. Major oil companies accept the conditions and costs as a reasonable price to pay, but some companies found the conditions restrictive and the charges payable to CUCBM excessive relative to the benefits. Some expressed disappointment at the level of reciprocal assistance from the Chinese partner and felt that the large investment in capacity-building was ineffective, others were reasonably satisfied. Common concerns expressed by foreign operators were difficulties of locating and accessing good quality coalfield exploration data, and the lack of transparency in identifying and allocating exploration blocks with no advertising or bidding processes.

Not all responses were negative, some major foreign investors and operators perceiving that CBM in China is attractive due to:

- Clear centralized, regulatory regime for participation in exploration;
- Strong willingness to attract foreign investment;
- Standard PSC terms;
- Extensive coal basins;
- Reasonable geological conditions – seam thicknesses, gas content, permeability;
- High growth gas market, albeit off a low base; and
- Reasonably attractive gas prices.

Financial barriers to CMM development

Although there are favorable policies to promote CMM projects in China, development of the resource is slow. Lack of funds in Chinese enterprises hinders local investment, and bureaucratic processes, safety issues and market concerns deter foreign investors. Investment in CMM is limited because many schemes are too small to interest Financial Institutions (FIs), foreign investors or large international companies. Local financing facilities are needed to encourage development, and local banks need to develop the skills to understand and analyze the projects. The mining enterprises themselves should be capable of preparing clear, rational proposals including an assessment of risk. Capacity-building for mines is needed in project development, appraisal, monitoring, financial and risk analysis.

Those foreign companies actively seeking projects sometimes find the amount of information provided is inadequate and insufficiently detailed. Mining enterprises and other Chinese organizations seeking to promote their projects need to do more to increase the chances of attracting external funding. Overseas investors will need a great deal of information before they will consider investing in a project in China. They need to satisfy themselves that a project is both technically and financially feasible and will need to conduct due diligence investigations to confirm the authenticity of information, its completeness and its interpretation.

There must be a potential to generate profit to attract investment. Chinese engineers tend to explore the technology and determine what can be technically achieved before considering financial viability. For this reason, many projects viewed as exciting and noteworthy by their Chinese proponents may attract little interest from investors or FIs.

Clean development mechanism

CDM allows developed countries to achieve part of their binding Kyoto GHG emission targets by purchasing Certified Emission Reductions (CERs) from qualifying GHG emission reduction projects in developing countries such as China. A prerequisite for a CDM project is that it should contribute to sustainable development as defined by the host country. The CDM Executive Board (EB), appointed within the United Nations Framework Convention on Climate Change (UNFCCC), decides on the validity of the methodology for generating CERs as well as the acceptability of projects. Once a methodology has been accepted, this sets the standard for other similar projects worldwide.

CDM has engendered considerable interest in China and the process is actively supported by the government. CDM represents a major financing opportunity for CMM utilization schemes. Many of the large coal mining groups are developing CMM CDM projects (Table 4.1) and the expected total annual emission reduction potential is over 7.7 Mt CO_2.

However, application of CDM to CMM utilization schemes has suffered some setbacks. Delays in implementation were experienced due to five different methodologies, all relating to projects in China being submitted for approval by the EB at around the same time. A new consolidated methodology for CMM (ACM0008) was finally agreed at the end of November 2005.

There could be many more CDM projects at coal mines, but difficulties in obtaining good quality data and information, safety issues relating to use of low purity gas, a lack of understanding at mines on the requirements of CDM, shortage of capital and insufficient technical capacity to develop CDM projects is limiting progress. Furthermore, the government's refusal to accept revenue-sharing from CERs has removed a key market driver and is deterring investment in CMM utilization. Nevertheless, the CDM process has been successful in stimulating an increase in gas utilization projects at coal mines which previous government instructions and incentives failed to achieve.

Substantial investment in safety improvements, supported by central government funds, has led to widespread installation and use of continuous monitoring systems recording gas flow and purity, but there are reliability issues with these systems and reliance is placed on manual measurements at many mines which will not satisfy the requirements of CDM. The CDM process will require project mines to strengthen their measurement capability and the spin-off benefits will ultimately be the availability of more reliable monitoring equipment, efficient and professional service companies and safer working conditions.

Table 4.1: Coal Mining Groups with Current or Pending CDM for CMM Projects

Company	Province	Projected Annual Emission Reduction $ktCO_2$ Equivalent
Fuxin Coal Mining Group	Liaoning	610
Yangquan Coal Mining Group	Shanxi	1,500
Jixi Mining Group	Heilongjiang	350
Jiaozuo Coal Mining Group	Henan	350
Huainan Coal Mining Group	Anhui	178
Jincheng Coal Mining Group	Shanxi	2,200
Hebi Coal Mining Group	Heilongjiang	50 (estimated)
Wanbei Coal and Electricity Group Qidong Coal Mine CMM Power Generation Plant (Suzhou)	Anhui	56 (estimated)
Tiefa Coal Industry(Group) Company Limited	Liaoning	770
Songzao Coal & Electricity Company Limited	Chongqing	630
Hegang Coal Mining Group	Heilongjiang	62
Ningxia Coal Industry Group Co. Ltd.	Ningxia	150
Shuicheng Mining Group	Guizhou	750
Huaibei Mining Group	Anhui	100

Source: CCII.

Health, safety and environmental barriers

Health, safety and environmental issues are important to foreign operators anxious to defend a responsible corporate image. Safety concerns have been instrumental in tempering foreign investment in coal mining, and even CMM projects with some companies. However, as the risks associated with surface CBM activity are relatively low and controllable, this issue has not arisen. Nevertheless, foreign consultees expressed concern about the large number of staff employed by contractors and the potential for economic imperatives to outweigh focus on health, safety and environmental management. Drilling contractors require education in site environmental controls including safe disposal of drilling fluids and lining of lagoons.

Health, safety and environmental management are mentioned in CBM PSCs and foreign partners have placed considerable emphasis on trying to achieve these standards:

- Operations to be conducted according to international practice;
- Best efforts to protect the environment;
- Securing of health and safety of personnel;
- JV partners to be liable for economic losses caused by pollution;
- Regular auditing; and
- Rehabilitation.

It is reasonable to expect that existing coal mine operations should take precedence over the exploration for surface CBM reserves. In the event of an incident or serious accident arising due to conflict between surface CBM and underground mining activities, and resort to legal redress, the outcome would be uncertain. Such uncertainty is unacceptable to most foreign companies and constitutes an investment barrier.

No significant improvement has been achieved in the underground coal mine safety in 2005, despite all the efforts of government. The number of fatalities from 3,341 coal mine explosions, fires and floods was 5,986, nearly level with the 6,027 people killed in 2004 (NDRC). The number killed in major coal mine accidents, those involving more than 10 deaths, jumped 60 percent to 3,586. Coal output rose 7.9 percent in 2005 to 2.11 Billion Tons (Bt), with the average number of deaths per Mt at just over 2.7. The 0.7 percent decline in coal mine deaths last year fell far short of the government's goal to reduce coal mine fatalities by at least 3 percent in 2005. Work safety officials recently announced their goal for cutting coal mining deaths in 2006 was 3.5 percent, but stated that the target would be difficult to attain. The petroleum industry is similarly afflicted. Sixty people died in 161 accidents in petroleum and petrochemical operations, 29 percent more than in 2004.

These poor results show that there are serious safety failings in the coal and petroleum/natural gas industries. Therefore, it is important that no new major risks are introduced in the pursuit of maximizing energy recovery and reducing GHG emissions from coal mines.

The use of low purity CMM (<30 percent CH_4 by volume) which includes potentially explosive mixtures for power generation at coal mines in China, for example, by Fuxin and Huianan Mining Groups, although a sound technical achievement, is inherently dangerous and would not be condoned by international engine manufacturers neither would it be accepted by mine safety regulators in industrial countries. Transport of flammable CMM mixtures is highly undesirable and storage of large volumes of explosive mixtures, or near-explosive mixtures of CMM in gas holders at the surface is unacceptable as a small leak and a spark could cause a catastrophic explosion. CH_4 concentrations in the range of 5-15 percent in air are explosive and good mining practice is to design CH_4 drainage systems to ensure gas is captured and drained at higher and safer concentrations.

The former Ministry of Coal Industry introduced a national regulation requiring the CMM for utilization in China to have a CH_4 concentration of at least 30 percent. This regulation is still extant and is consistent with mine safety regulations in other countries. The acceptance and encouragement of CMM utilization technology which can use low purity CMM removes the incentive for a coal mine to improve its CH_4 drainage practices and safety performance. While yielding a short-term energy and environmental reduction, a better and more sustainable result would be obtained if gas drainage standards were improved. Gas drainage systems which carry mainly air are inefficient and ineffective. The fact that mining groups are prepared to ignore safety regulations, with the support of local government in some instances, sends warning signals to responsible investors and project developers. This is a sound reason for making the safety ratings of the mines[4] public so that the investor will at least be aware of the risk, and it may provide incentives for the mines with lower ratings to improve.

[4] *Assessed by the State Administration of Coal Mine Safety (SAMS)and provincial safety bureaus.*

Market barriers

Potential gas markets for both CBM and CMM include a clean substitute for coal gas generated in town gas plants, industrial thermal and chemical use, power generation or major long distance pipelines. Market potential is determined by energy demand, competition with other fuels especially natural gas, transport costs and price.

The principal market issues for CBM raised by foreign consultees were the low cost and abundance of coal, creditworthiness of buyers, lack of confidence in the security of supply given the immaturity of CBM industry and limited success to date, and the immaturity of the gas market.

Coal in China is substantially cheaper than natural gas and, therefore, government intervention is needed to reduce coal burn in cities and introduce more clean energy to improve air quality. This move is environmentally policy-driven with changes such as coal-to-gas-switching enforced by administrative order in some cities and encouragement for using market-based instruments in others. Benefits of these changes include improved health, less absenteeism from work becouse of illness and a reduced demand on health services. Increased use of gas is, therefore, playing a key role in many cities striving for environmental improvement, including Beijing. Both CBM and CMM can contribute to this process in coal mining areas.

An estimated annual gas consumption of 800-900 PJ/year (around 25 Bm^3) in China is expected to grow at 10-12 percent per year, concentrated mainly in eastern and north-east China. Some estimates indicate an annual demand of 3,570 PJ by 2010. The gas supply is all currently domestic, although natural gas could be imported from east Siberia if political and financial issues can be resolved. The proven natural gas reserves in China are 55-60 Tcf but continuing exploration is raising this figure. Major gas transmission pipeline projects have been planned and some are under way. The first leg (1,250 km) of the West to East transmission pipeline linking Shanghai to the Ordos Basin is operational and the 2,400 km extension linking Tarim and Qaidam Basins should be operational by 2006. A transmission pipeline (1,000 km) linking the Sichuan Basin to the West to East pipeline between Ordos and Shanghai may be available some time after 2010. LNG import terminals in Guangdong and Fujian will supply 5-7 Million Tons Per Annum (Mtpa) (270-370 Peta Joules [10^{15} Joules] [PJ] per annum) by 2008-09. Ex-field (compressed) prices vary from 0.6 to 1.0 yuan/m^3 (US$2.05 to 3.45/ Giga Joules (10^{12} Joules) [GJ]), with city gate prices ranging from 1.30 to 1.60 yuan/ m^3 (US$4.50 to 5.50/GJ). These natural gas developments will still leave plenty of room for CBM supply.

Establishing new city gas supplies involves substantial investment in trunk pipelines and downstream by users. Once the gas arrives at the city gate, a distribution system is required to carry it to the consumers, and the consumers need to purchase suitable equipment and burners to use the gas. A high gas price is desirable to encourage construction of pipeline infrastructure, but has to be weighed against the need to stimulate users to convert to gas. At present, gas use and gas prices are largely determined by the government and fuel choices are often limited.

VCBM can benefit from the evolving gas market but the CBM industry alone is too small to drive infrastructure development. Commercial VCBM development may, therefore, not advance rapidly until the natural gas industry has matured and established a ready market which VCBM with its free pricing structure, can tap into with a small price differential.

The East-West natural gas pipeline is being cited as the potential saviour of CBM/VCBM in

Shanxi, but capacity limitations and the cost of compression, metering, transport and marketing may exclude access by CBM.

CMM is not a threat to CBM or natural gas usage as it is a lower quality product. In western countries, CMM would not be distributed for domestic use as it does not meet minimum quality standards. In China, there are various standards for various gas qualities. Provided the concentration is >30 percent, it can be used for domestic purposes. A high natural gas price will encourage the use of CMM which, due to its lower purity, will be priced lower.

Electricity may be easier to distribute to consumers than gas, but the present regulatory framework does not favor small-scale power generation other than for use by the mines consuming their own CMM. The acceptability of small-scale power outputs to the grid varies from place to place. Some mines have no problems negotiating a grid connection but are required to deliver their power to the grid and, then, buy-back what they need at a higher price. The overall situation is expected to improve in 2006, with easier access to the grid for all as a result of the new Renewable Energy Law, subject to its adequate enforcement.

Technology barriers

Technology barriers include difficulties of extracting gas from low permeability coal seams in advance of mining and for VCBM production; gas drainage methods not suited to the geological and mining conditions, unreliable monitoring equipment and inadequate underground drilling equipment leading to poor gas drainage performance and reluctance by some foreign technology providers to enter the China market due to commercial risks.

Extracting gas from low permeability coal seams

The most common request from Chinese mining companies is for solutions to the problem of predraining gas from low permeability seams, and from VCBM developers on how to increase gas flows in surface wells. No commercially feasible, large-scale, artificial permeability enhancement techniques are yet available, although technologies are currently being developed to increase (enhance) the volume of gas recoverable from established coal seam reservoirs. However, the immediate needs of conventional VCBM are for improved screening techniques to identify geologically favorable sites where advantage can be taken of natural permeability enhancements.

CMM capture and quality improvements

SACMS believes that to ensure safe conditions, gassy mines should drain gas both before and after mining (predrainage and postdrainage). Although this guiding rule is well meant, the prescriptive requirement does not encourage account to be taken of the gas emission characteristics of the workings or the geological and mining conditions when determining the most appropriate CH_4 drainage strategy.

In China, many mines have multiple longwall production faces in various combinations of manual, semi-mechanized and fully mechanized. Gas drainage is only needed on the gassy coalfaces, so, not all production units are necessarily drained. The cumulative effect is, therefore, a low overall mine gas capture efficiency.

Drained CH_4 concentrations in Chinese coal mines tend to be highly variable and purities of 10 percent and less are not unusual. Observations made during field visits indicate CH_4 concentrations typically in the range 25-35 percent with concentrations above 50 percent being achieved at a few mines with well managed drainage systems matched to the geological and mining conditions. The problem of maintaining CH_4 purity is a significant factor in finding CMM markets and optimizing use. Poor CH_4 quality is often traceable to use of drainage methods which do not match the mining and geological conditions and poor housekeeping underground.

Standardized designs tend to be imposed, which are not always appropriate to the geology and mining conditions, although it is conceded that for a gassy mine to have at least installed a gas drainage system is a step in the right direction. Individual KSOCM have little scope to make technical changes and improvements – these generally have to be approved by referring to higher levels within the mining groups/bureaus and, in some instances, to the provincial government. The fact that provincial vice governors with safety responsibilities are now held accountable for serious mine accidents could further inhibit innovation due to the extension of the decision tree. Initiative may be stifled but the risk of a bad decision is reduced. The net result will be slower progress.

Gas monitoring systems are being widely installed but reliability is sometimes questionable due to the poor quality of equipment, and lack of calibration and maintenance facilities. Suitable, reliable, advanced monitoring systems are readily available in the international market, but the protracted electrical safety approval procedures are delaying their introduction. The lack of harmonization between Chinese and international mining equipment electrical safety standards also precludes Chinese manufacturers from access to world markets – desirable as a driver for improvement in product performance and quality which will ultimately benefit the Chinese miner.

Drilling equipment for gas drainage

Many of the current designs used in China are based on obsolete machines with the corresponding performance limitations. More efficient modern equivalents are needed. Efficient and safe drilling requires attention not only to the drilling machine but also to the drill bits, rods, water and hydraulic power supply and safety control systems. Chinese mines do not drill boreholes through a safety device which allows any high pressure gas and water that is encountered to be controlled. This equipment is mandatory in U.K. coal mines and its use should be urged in China as an important safety precaution.

Coal seams with high gas contents need to be predrained either to reduce outburst risk or to reduce coalface gas emissions thus facilitating safe working. Although not always successful in terms of gas volume drained, many mines persist with in-seam drilling in China to comply with the safety requirement to drain in advance of mining if practicable. Many mines believe the introduction of advanced guided drilling systems will solve many of their in-seam gas drainage problems. While such techniques have a role, this technology will not necessarily be suited to the geological conditions in many of China's coalfields. Furthermore, most mines do not have the capability to operate and maintain complex drilling systems.

Development of domestic technology and technology transfer

Manufacture of gas drainage drilling machines, gas extraction pumps and monitoring systems is dominated by the various branches of China Coal Research Institute (CCRI), the Chongqing and Fushun branches providing most of the specialist CMM-related services. This company has a virtual monopoly and is keen to extend its business further and introduce new technologies from other countries. However, there is an inherent limitation on technology transfer in that the foreign Original Equipment Manufacturers (OEMs) are reluctant to risk loss of Intellectual Property Rights (IPR). The coal mining sector in China is heavily reliant on both licensed and illegally copied equipment designs with the government taking no substantive action to protect IPR. Low labor costs, cross-subsidies and near monopoly advantages make market entry to foreign suppliers difficult. Government also complains publicly about the cost of imported equipment and mines are encouraged to buy local equipment. As a consequence, there is insufficient competition to drive Chinese OEMs to increase R&D expenditure and develop more modern products, low pricing limits investment available for developing new products and many mines do not have access to the latest technology, which they desperately need to raise performance levels. Without access to the latest technologies, China will not be able to achieve improved CMM capture and utilization.

The application of technology, whether domestic or foreign, is inherently limited by the capacity of designers and operators, and also by the diffuse, inadequate communication between actual users at the mine and designers, due to the intervening hierarchy of group and mine management. The design function usually resides with a dedicated Mine Design Institute. There is a need for capacity-building among technical staff and for more streamlined management systems at mines.

Introduction of new technology

China could benefit from a wide range of imported gas control technology for its mines and CMM utilization schemes. However, foreign companies with key technologies, reluctant to enter the China market, cite the following reasons:

- IPR concerns. Patent law is being more strongly enforced but manufacturers still need to exercise caution;
- Equipment being blamed for client failings thus damaging the credibility of the manufacturer in the international marketplace. For example, inappropriate equipment selection, inadequate maintenance and lack of investment in training of operators. Suppliers should recognize the importance of providing "whole lifecycle" support to consumers to ensure equipment is properly selected, commissioned, used, serviced and refurbished to ensure maximum availability and performance. Training should be included as part of equipment packages;
- The higher cost of imported equipment deters some Chinese buyers but many understand the benefits of using robust, imported equipment manufactured to high standards with high grade materials and with performance abilities in excess of domestic equipment;
- Imported coal mining electrical equipment must be submitted to an assessment, inspection and approvals process before it can be used in a mine in China. This process can be cumbersome, costly and time-consuming. Unless exempted, explosion proof and intrinsically safe equipment cannot be used in a Chinese coal mine until awarded the MA ("Mei Anquan [coal safety mark of approval"]) mark. The Chinese standards are based on an outdated international standard EN5004 (1968) which not only hinders import of modern, safe, efficient mining equipment, but also deters Chinese manufacturers from modernizing their designs and participating fully in international markets. This barrier prevents coal mines sourcing the most effective equipment for their needs; and
- Tendering procedures are not always transparent and are rarely performance-based, thus leaving no incentive for innovation. Recently, tenders for a large CMM project had to be reissued because there were no qualified bidders. The announced cost range for the successful bids was too low and qualified bidders declined to bid. The tender package had to be revised.

Reducing technology risk

CBM and CMM technology development in China has been assisted by international donor, bilateral aid and lending agencies for the past decade with efforts directed mainly at reducing technical and financial barriers and providing capacity-building, but with mixed results (Annex VII). Internationally financed activities have helped to reduce technology risk through demonstration projects, which enable new technologies to be introduced from other countries and technically evaluated. Demonstration projects are designed to highlight technologies or processes which are relevant, practicable, which will result in a marked improvement in performance and which can easily be replicated. Any equipment involved should be available from a supplier who can provide technical support and guarantee spare part availability in China, rapidly and at reasonable cost. Some demonstration projects in China have shown that an advanced technology can be made to work by foreign experts with expensive foreign equipment – for example, the drilling of guided long hole boreholes above a longwall goaf. While the technical result may be excellent, the impact can be negligible and too few CBM/CMM projects in China have been widely replicated. A notable success has been a surface goaf drainage demonstration at Tiefa, which has seen active replication recently in response to government pressure to improve gas control within the coal mining sector.

To ensure success, technological applications require support from experienced specialists. In areas where a technology is in widespread use, specialist service companies have developed to meet the needs of the industry. These service companies may not exist, or their skill base may be too limited, in areas into which a new technology is implanted. This support base takes time to develop and government assistance would be helpful in its early stages.

Principal barriers to development of CMM utilization schemes

There are a number of factors which hinder CMM development by coal mining enterprises. Some of these are domestic; others involve prospective foreign participants, and include:

- Attempting to transplant gas drainage and utilization technologies which may not be appropriate for Chinese conditions both in terms of mining and culture;
- Insufficient technical information and guidance available in Chinese to mining enterprises;
- Underestimating research, effort and investment needed underground to optimize gas availability and quality;
- Concern about work safety standards by foreign investors;
- Shortage of capital but any foreign interest in the project, however small, can increase the chances of obtaining finance from domestic government sources;
- Lack of transparency to foreigners;
- Taxation (although ameliorated by tax relief incentives);
- Inability to negotiate product price before formal approval of feasibility study by the development and reform commission; and
- Local energy policy and gas/electricity supply and distribution complexities.

Ingredients of good CMM projects

Foreign and domestic developers are fairly clear about the ingredients of a good project. Nevertheless, they also recognize that no perfect projects exist. Project size is important, if too small investors will not consider the start-up and administrative costs worth the effort for a small gain. Attractive projects are those where:

- The aims are clearly defined, understood and achievable; clearly presented factual information is essential to attract external interest in a project;
- There is a clear management structure and decision-making process;
- Local or central government approval has

been obtained and the applicability of any tax incentives confirmed, or at least in the case where the project is being proposed jointly by a foreign partner and a local entity, the procedure should be transparent and a procedural list for the approval process should be supplied so that it can be used as a checklist;

- Technical risks are quantifiable and controllable with provision for continuing technical support at project inception and afterwards;
- The requisite technology is suitable and applicable to the location and within the skills base of the community;
- Revenue can be generated at an early stage;
- Consumers have been identified and firm supply contracts negotiated;
- Prices are firm and set to rise (a difficult one to forecast);
- There are significant environmental and social benefits;
- The return on investment is commensurate with the risk;
- Payback of capital is possible in two or three years;
- There are long-term gas sales prospects;
- There are quantifiable environmental and social benefits; and
- Success can be replicated elsewhere.

5. Comparative Experiences of Other Countries

CBM and CMM Resource Management

Introduction

Internationally, distinctions are made between owners of the surface land, mineral rights and gas rights. In many countries, gas rights (CMM or natural gas) rest with the national government, which, in turn, issues licenses for resource development according to its specific laws. CMM use authorization typically carries with it requirements for payment of fees or royalties, although such payment may not be required for on-site uses. For example, the government in Australia waives fees for gas used on-site. In some cases, local (provincial) administrations may impose licensing or other requirements which are in addition to those levied by the federal government. Users also must perform a reasonable amount of exploration or development to retain a lease. In some cases, the holder of coal exploitation rights can also develop the CMM resource. To do so, however, would require securing a CH_4 development license separate from that for coal development.

CBM is generally treated under conventional oil and gas licensing regimes in European countries, but in many countries the ownership status of CBM or CMM is inconclusive because it has not been legally tested. The legal ownership of VAM does not appear to have been defined anywhere since it has not yet been established as of commercial value, but it is likely that countries with a definitive process for gaining rights to CMM would extend them to include VAM.

Germany

Leases have been awarded in the Ruhr and Saar basins and a number of CBM wells have been drilled. Germany currently has a number of commercial CMM extraction schemes operating at working and abandoned mines. Abandoned Mine Methane (AMM) achieves a status and price advantages comparable with RE in Germany.

Under the current law, "mine gas" is a resource which is not owned by the person who owns the ground or land. In order to explore and/or extract it, a two-tier licensing system is in place. An exploration license entitles the holder to locate (explore), to use the resources extracted during the exploration process and to build the structures and facilities to undertake exploration for a certain prospect. There can be more than one exploration license. An exploration license is granted for a maximum of five years with the possibility of a three-year extension if the resource, despite adherence to the planned and agreed exploration program, has not been explored sufficiently. An extraction license entitles the holder to locate, extract the resource and any other resource in the same field and own it; it can be obtained for a maximum 50-year period and will be assessed on a case-specific basis. Extensions are possible. Before any exploration or extraction licenses are considered, a program has to be submitted demonstrating that the planned activities are sufficient and within an acceptable time frame for the type, scope and purpose of the exploration/ extraction. A license can be refused if found to be inadequate with respect to any of the following factors:

- Exact identification of resource to be explored/extracted;
- Appropriate person;
- Sufficient funds;
- Sharing of knowledge;
- Public interests;
- Field boundaries and records; and
- Feasibility for a proposed extraction technology within a given time frame.

A license can be withdrawn or surrendered.

United Kingdom

The offshore U.K. sector of the 36-year-old North Sea oilfield has established the country as a center for international oil and gas companies, some of which are developing onshore CBM/CMM interests as offshore resources decline. Following the May 2000 ninth round of onshore licensing, almost half of the 123 blocks licensed were for the exploration of CBM and CMM, the latter from abandoned coal mines.

The total CBM resource in the United Kingdom is estimated as 105,000 PJ (3 Tm^3) but only a small proportion of the resource is potentially recoverable (3 percent at most) due to generally low seam permeability, surface development and local government planning approval constraints. The high costs and uncertainty of planning applications and planning enquiries is a major deterrent to investment in VCBM.

The Petroleum Act of 1998 vests ownership of the petroleum resources in the Crown and allows the Secretary of State for Trade and Industry to grant Petroleum Exploration and Development Licenses (PEDL). The operator must also obtain consent through the DTI to drill a well, submit plans showing precisely how the well is to be engineered and provide evidence that the requisite planning permission has been given. Likewise, consent is required to abandon a well and the operator must satisfy the Health and Safety Executive (HSE) on how this is to be achieved safely. CBM developments also require permission from the coal owner (the Coal Authority) before the seams can be accessed.

Coal is under separate ownership to petroleum and CBM. Under the Coal Industry Act of 1994, ownership of unworked coal was transferred from the British Coal Corporation (the former State-owned coal mining company) to the Coal Authority. It is the Coal Authority's policy not to grant access to areas of the coalfields or to surface land in its ownership for the purpose of CBM extraction unless a petroleum license is held for the area in question. In addition, the area subject to the access agreement will not be greater than that defined in the relevant petroleum license.

CMM Ownership, licensing and regulation: The U.K. PEDL license includes exploration and development of AMM extraction projects, but CMM extraction from working mines is covered by a separate "Methane Drainage License (NDL)." Some mines utilize or flare the gas produced under their MDL for environmental reasons. The rights of MDL and PEDL holders do have some overlap but conflicts have not been sufficient to drive the parties to court to obtain a legal opinion.

Coal Authority licensing arrangements: In addition to the PEDL license, certain rights will be required from the Coal Authority to enable a CMM or CBM project to proceed. If a CMM proposal involves the occupation of surface property or a mine entry owned by the authority, a lease to occupy the property will be required.

This takes a standard format and copies can be supplied on request. Where entry into coal or coal workings is required by drilling, an access agreement will need to be entered into. A standard form of agreement is available from the Coal Authority.

Interaction with coal mining activities: In the United Kingdom, coal mining is likely to be given priority over CBM exploration and development where overlap could occur in terms of timing. However, the safety and environmental benefits of removing gas from areas which might be mined some time in the future, would be recognized, provided that assurances could be given regarding safe sealing of boreholes on abandonment and prevention of damage to strata which could jeopardize mine roof control in the future. As the coal mining industry is shrinking rapidly, such interactions are rare and the procedure is precautionary. The Coal Authority will require the developer of a CBM/CMM/AMM project to provide a comprehensive risk assessment covering potential impacts of the proposed scheme including interaction with mine operators and surface safety considerations. Applicants are required to sign an "interaction agreement." The term "interaction" is used to describe the physical effects, which activities connected with any coal or coal mine may have on other such activities (including their subsidence effects), or on other interests in coal. Those effects include water or gas migration and the results of a withdrawal of lateral or vertical support. Interaction can, therefore, occur in situations where the activities are separated by considerable distances. The interaction agreement binds the signatories to a process of notification, discussion, mutual consent, and an obligation to act reasonably.

The Coal Authority has prepared a CBM map which indicates "Category 1" areas of the coalfields in Great Britain where access for the purposes of VCBM extraction is most likely to be restricted due to coal mining operations. Where an area (or any part of it) which is subject of a VCBM application falls within a "Category 1" area, the Authority will consider the implications of the application for existing and future coal mining. Where rights to the coal have not already been granted, the Authority may be prepared, after seeking any expressions of interest for coal mining purposes through the publication of the application, to adopt a flexible approach in the granting of access rights.

Where the area which is subject of a CBM application falls into "Category 2" (lying outside defined areas of coal mining interest), the Authority will normally provide access to the applicant on standard terms with a minimum of additional conditions, but reserves the right to seek expressions of interest in the area concerned through the publication of the application; and to protect mining prospects which have been identified within these areas before the application was received.

Australia

The Queensland State government has also developed and implemented interaction agreements to enable CBM to coexist safely and without conflict with coal mining activities. The exercise in the United Kingdom has been largely theoretical as CBM development has stalled, but in Australia it has been proven in practice.

United States

Ownership of CBM is a contentious issue in some of the coal mining states in the United States. Typical issues revolve around: 1) conventional oil and gas leaseholder's right to drill shallow CBM wells; 2) ownership of CBM separated from coal during mining; and 3) whether to include CBM as a mineral intended to be granted in severance deeds. The apparent need for costly and delaying case-by-case litigation to establish ownership where conflicts are identified must be avoided by China in establishing property law relating to CBM and CMM ownership, and rights to extract and use the gas.

Within the U.S., royalties for the use of CMM are to be paid to the owner of the gas estate. Generally, royalties of 12.5 percent are owed to the federal government for all mineral leases (including CMM) from federal lands. Royalties for privately-owned gas estates are negotiated on a case-by-case basis. Through the North American Free Trade Agreement (NAFTA), enacted in 1994, the U.S. has removed all gas tariffs for gas exports/imports to or from Mexico and Canada.

Promoting CMM extraction and utilization

National climate change policies are the main drivers for CMM development whereas CBM tends to be favored as a clean energy for coal substitution. CMM released from working mines is viewed as an issue requiring immediate action as significant GHG emissions from working coal mines will continue unabated unless action is taken.

Australia and the United States, although failing to ratify Kyoto and, thus rejecting binding emission reduction quota, have, nevertheless, implemented effective policy for reducing CMM emissions. The once major coal mining industries of the United Kingdom and Germany are approaching extinction, but some of the closed mines continue to provide energy in the form of AMM which, for legal purposes, is also classified as CMM. Germany has elected to treat CMM as a special case with similar privileges to RE resulting in a massive boost to development of CMM projects at working and abandoned coal mines.

A variety of support mechanisms have been developed to encourage the use of CMM and CBM resources worldwide (Table 5.1). The mechanisms can be categorized as follows (DTI, 2004):

- Feed-in tariffs, which provide an incentive for electricity generation;
- Obligations, which provide incentives to specific market players to use specific resources by means of quotas/obligations and fines for noncompliance;
- Tax incentives, which provide investment and/or operational incentives;
- Grants, which provide capital expenditure incentives; and
- Other initiatives including information dissemination programs.

Table 5.1: Policies Stimulating Utilization of CMM (Adapted from DTI, 2004)

Policy	Description	Country	Scheme Status	Project Developer and Financing Benefit
Feed-in Tariff	Twenty-year guaranteed power offtake contracts given to the electricity generator	Germany	Appears successful with c.70 MW of generating capacity commissioned since inception. Applied to CMM and AMM schemes	Very attractive due to high tariff, guaranteed for a long period of time, greatly facilitating project finance
Obligation	Obligation on energy suppliers or generators to limit CO_2 emissions (Gas Abatement Scheme)	Australia	Reported to have attracted interest from CMM industry which aims to accredit CMM schemes	Market-driven incentive which, if properly designed, can provide economic impetus to developers and access to project finance.

Policy	Description	Country	Scheme Status	Project Developer and Financing Benefit
Tax Incentives	Production Tax Credit; a 10-year guaranteed tax-driven incentives designed to encourage electricity generation	U.S.	Scheme not applicable anymore to CBM but perceived to have contributed to the exploitation of more than 10,000 wells by the end of 2000	Effectively a feed-in tariff in disguise increasing certainty over level of income stream, thus facilitating project finance
Grants	50 percent grant toward project costs	Australia	Five CMM projects have been funded. Once all funds have been allocated, no further schemes are admitted. CMM projects compete equally with energy-saving and energy efficiency projects for support	Grants can provide a significant boost, reduce project risk for the recipient and reduce resistance to introducing and scaling up technologies not previously proven at large scale

Source: Adapted from DTI (2004b).

Some countries have additional support mechanisms to encourage destruction of CMM surplus to utilization capacity. For instance, the U.K. carbon trading scheme allows credits to be earned by flaring gas which cannot be utilized. However, the same benefits are not yet available to projects involving AMM, as this gas source is not included in the U.K. national GHG inventory. Neither is the government prepared to grant RE status to CMM/AMM extraction and use as it would place an obligation on electricity buyers which would be inconsistent with the liberalization of the market. AMM is not important in China at present but any specific policy for promoting CMM use, or reducing emission, should include AMM to ensure consideration is given to the impact of the full mining cycle.

Feed-in tariffs – Germany

AMM/CMM is supported in Germany by a "feed-in tariff" (DTI/Pub URN 04/933). The Erneuerbare Energien Gesetz (EEG) or "Renewable Energy Sources Act" (2000) of the German federal government, sets out the terms under which a 20-year guaranteed power offtake tariff is granted to specific Renewable Energy Technologies (RETs). Whilst CMM is not considered by the Germans as a RE source, the use of CMM for electricity generation is considered to present environmental benefits and, as such, was included under the Act. China has mirrored the German approach in its Renewable Energy Law but has not included CMM as a beneficiary of the financial incentives.

Electricity generated from AMM/CMM projects benefit from a predetermined power offtake price of US$96.9 Mega Watt (s) Per Hour (MWh) for the first 0.5 MW and US$84.0/MWh thereafter, given to renewable technologies. This is significantly higher than wholesale electricity prices (c. US$36.6/MWh) and consequently provides a strong incentive to CMM developers to exploit the full potential of this energy source. The EEG also provides a legal framework aimed at facilitating the integration of such technologies to the national energy supply. This is achieved by way of an obligation placed on the grid operator to connect renewable (and AMM/CMM) installations to their network and bear the costs of the grid upgrade costs; and granting priority of dispatch to electricity generated from these sources. The extra costs are all passed onto the electricity consumer (and hence were determined not to be State- aid by the European Commission (RE)).

The introduction of this incentive has been beneficial to the development of CMM/AMM electricity generation projects – three CMM/AMM electricity generating plants with a total capacity of 6.27 MW, previously regarded as being uneconomic, were guaranteed continuing operation and just under 70 MW of new capacity was added since its introduction in 2003.

Obligation on energy suppliers – Australia

Whilst the Australian government can provide support to CBM/CMM projects by way of a 50 percent grant at federal level, State incentives such as the Gas Electricity Certificates (GECs) program in the State of Queensland and New South Wales Greenhouse Abatement Credits (NGACs) in the State of New South Wales can provide additional market support to CBM/CMM schemes by way of a market obligation placed on energy suppliers. The State of Queensland has set an objective of increasing the proportion of electricity generation from gas to 13 percent of the total electricity generation as a move away from coal generation. Electricity suppliers are required to source GECs from generators of electricity using natural gas, coal seam, landfill, or sewage gas to comply with their obligation (in the same way as the RE obligation in the United Kingdom). GECs appear to be traded at just under US$7.6/MWh, providing the generator with extra income on top of wholesale electricity prices.

New South Wales Greenhouse Gas Abatement Scheme: CH_4 from coal mining accounts for 8 percent of New South Wales total annual GHG emissions, mostly from underground operations with two or three in-ventilation air. In addition to conventional CMM uses, technologies are being developed to remove CH_4 from ventilation air and generate power. Harnessing CMM is considered to be one of the lowest cost forms of GHG mitigation by the New South Wales government.

The NGAC arrangement in New South Wales is somewhat similar to that in Queensland in that a demand is created by way of legislation, thus creating a market for certificates. The scheme commenced on January 1, 2003, and remains in force until 2012. Mandatory GHG benchmarks are imposed on the following parties to abate emission of GHGs from electricity consumption:

- New South Wales electricity retailers;
- Consumers with loads greater than 100 Giga Watt (s) Per Hour (GWh); and
- Parties carrying out significant State development designated by the Minister of Planning.

A State GHG benchmark of 8.65 t CO_{2e} per capita was set for 2003 which progressively drops to 7.27 t in 2007 and remains at this level until 2012. Participants in the scheme surrender New South Wales GACs to demonstrate that they have reduced their GHG emissions. The GACs can be traded between other benchmark participants. At the end of each year, participants submit a statement detailing their emissions and any abatement certificates held. Should there be a shortfall (that is, the benchmark is not achieved), a penalty is due (excess emissions currently attract a penalty of US$7.9/t CO_{2e}. Shortfalls of up to 10 percent can be carried forward to the next year, but must then be abated in that year, otherwise, the penalty is due. Accredited parties engaged in any of the following activities can create NGACs through various routes:

- Low emission generation of electricity (generation);
- Activities which result in reduced consumption of electricity (demand-side abatement);

- The capture of carbon (C) from the atmosphere in forests (C sequestration); and
- Activities carried out by elective participants which reduce on-site emissions not directly related to electricity consumption.

One GAC represents the abatement of one ton of CO_{2e} with a value in the region of US$3.8-11.4. The New South Wales government requires CMM/CBM projects to be associated with current mining operations and also allows large users to obtain GACs for the flaring of emissions from active mines. Venting of drained CMM is not permitted, the gas must be either used or flared. Mining legislation requires drained gas to have a safe concentration to extract. These regulations, combined with strong incentives (GAC and GEC) to avoid emissions and generate electricity from CMM, provide an effective mechanism for both reducing GHG emissions and exploiting the energy potential.

National certificate trading schemes can provide a strong incentive to technology development in the situation of high-expected demand – thus high certificate prices – and the availability of long-term power offtakes. Certificate contracts at suitable prices from creditworthy entities is, however, crucial to satisfying the requirements of both equity providers and project lenders. The key benefit of such support mechanism lies in its ability to provide ongoing revenues, contributing to project cash flow stability and debt repayment ability.

Company GHG strategies

International coal mining companies invariably include GHG emission policies in their environmental strategies. Demonstration of environmental responsibility is important for public and shareholder image. More importantly, early action and a proactive approach to emissions reductions maximize the chances of retaining competitive advantage in a world of increasingly strong response to climate change mitigation.

For example, Xstrata Coal in Australia has developed a comprehensive climate change strategy aimed at reducing GHG emissions per unit of production by 10 percent on 2003 data over five years. This will be achieved by investing AUS$9 million in clean coal technology, CH_4 utilization and C sequestration research and implementation over five years; joining the Greenhouse Challenge Plus – a voluntary program between industry and the Australian government to reduce GHG emissions; and addressing energy efficiency.

Production Tax Credits – USA

Until September 21, 2002, when the scheme expired, U.S. owners of wells which produce CBM were eligible for special tax credit treatment under Section 29(a) of the U.S. Internal Revenue Code. The S29(a) Production Tax Credit (PTC) provided a dollar-for-dollar offset to CBM generators for taxes payable under the general income tax regime. The PTC was available to CBM projects drilled by December 31, 1992, and was available for a period of 10 years from the date of project commissioning. The PTC was originally worth around US$0.95/GJ and around US$0.47/GJ toward the end of the scheme. Whilst PTC may not be the only factor behind the rate of growth of CBM industry in the United States over the last decade, it certainly has been a contributor which has led to more than 10,000 CBM wells being in production by the end of 2000. Some U.S. CBM industry experts believe that the tax credits allowed the developers to finance the pipeline infrastructure without which there would be no industry, others maintain that tax credits played little part and the existence of an extensive gas pipeline network was the chief motivating factor.

Grants – Australia

Capital grants, granted either automatically or by way of competitive tender, are a simple way of providing project support. This is the option which the Australian government has opted for under the Commonwealth Greenhouse Gas Abatement Programme (GGAP) to encourage the mitigation of emissions from CMM from mines and the generation of electricity from this fuel. GGAP is designed to reduce Australia's net GHG emissions by supporting practical and effective activities which will deliver substantial GHG emission reductions. GGAP is a key government initiative aimed at capping the country's GHG emissions to 108 percent of 1990 levels over the period 2008-12 under the Kyoto Protocol. With US$304 million allocated to the program, GGAP tends to support large-scale activities by way of grant support (up to 50 percent of the investment cost) through a competitive process which selects projects on the basis of the following key criteria:

- Support is only given to activities which would otherwise not be carried out without GGAP support ("additionality");
- Activities should lead to substantial emission reductions in the first commitment period under the Kyoto Protocol (2008-12); priority is given to projects which can deliver reduction exceeding 250,000 t of CO_2 equivalent per annum;
- Activities with a low cost per-ton-of-CO_2 saved are favored; and
- Projects funded under GGAP are expected to provide complementary benefits (for example, opportunities for rural and regional Australia, ecologically sustainable development, employment growth, the use of new technologies and innovative processes, and nongovernment investment). Grant payment is made upon achieving preagreed milestones.

Approximately, US$110 million was committed to support 15 projects with a total value of US$550 million under both Rounds 1 and 2 of the program. CMM projects which have received funding are:

- **German Creek colliery, Central Queensland (US$11.76 million)** – Installation and operation of equipment to generate electricity from CMM. This will achieve a projected abatement of 2.4 Mt of carbon dioxide equivalent (Mt CO_{2e});
- **Envirogen, New South Wales and Queensland (US$9.88 million)** – To install generators to burn CMM to produce electricity at several sites in New South Wales and Queensland. This will result in around 2.25 Mt CO_{2e} of abatement through cuts in CH_4 emissions and displacement of coal-fired electricity generation;
- **Centennial Coal, Newcastle (US$11.40 million)** – To link the air intake of Vales Point power station to the mine ventilation system of collieries south of Newcastle to capture CH_4 gas previously released into the atmosphere and burn it to generate electricity. This will result in abatement of 4.11 Mt CO_{2e};
- **BHP Billiton, Illawarra (US$4.56 million)** – To install a thermal oxidation unit ("*Vocsidiser*") at West Cliff colliery to burn air containing very low concentrations of CH_4 and generate electricity using a steam turbine, resulting in abatement of 1.04 Mt CO_{2e}; and
- **Envirogen, NSW South Coast (US$6.84 million)** – To install equipment at Bellambi mine to capture and burn CMM to generate electricity, resulting in abatement of 1.7 Mt CO_{2e}.

Grant funding can be a significant contributor to project economics and is often allocated to projects/technologies at the demonstration stage. However, in contrast to guaranteed power offtake contracts for instance, grants do not improve project cash flows or the certainty over project cash flows, and, therefore, do not directly contribute to satisfying lenders of project finance. Project finance providers therefore, often, assess the benefits of grant-assisted projects on a case-by-case basis.

Multilateral and bilateral CMM promotion initiatives

The United States has joined with Australia, China, India, Japan and South Korea to create an Asia-Pacific Partnership on Clean Development and Climate. This new initiative was announced on July 28, 2005, at the Association of South-East Asian Nations (ASEAN) Regional Forum in Vientiane, Laos. It aims to accelerate the development and deployment of cleaner, more efficient technologies to meet national pollution reduction, energy security and climate change concerns in ways which promote economic development and reduce poverty.

The leaders of the industrial world at the Gleneagles Summit (July 6-8, 2005) reaffirmed their commitment to supporting the UNFCCC and to working in partnership with emerging economies to achieve sustainable reductions in GHG emissions worldwide. Priorities included assisting developing countries to secure private investment and benefiting from technology transfer. Specific actions included encouraging CH_4 capture and beneficial utilization by supporting the Methane-to-Markets (M2M) Partnership, a global type of CMM clearinghouse.

Of the range, the variety of options for CMM utilization, internationally, power generation remains the most extensively employed due to its versatility. CMM power production projects currently exist in Australia, China, Germany, Japan Poland, Russia, United Kingdom, Ukraine, and the United States. Some 50 projects operating at abandoned and active mines range in output from 150 kW to 94 MW and total more than 300 MW (Coalbed Methane Extra, Coalbed Methane Outreach Program [U.S.[CMOP]], September 2005).

In November 2004, 14 countries entered into an agreement to reduce global CH_4 emissions, creating the M2M Partnership, a U.S. initiative. The founder-member countries include China (as well as Argentina, India, Russia, Australia, Italy, South Korea, Brazil, Japan, Ukraine, United Kingdom, Canada, Mexico, United States and Nigeria). In the summer of 2005, South Korea and Canada joined the forum. There are four technical subcommittees: coal, landfills, agriculture and oil and gas. At its meeting in April 2005, the M2M Coal Technical Subcommittee developed an action plan comprising priority, short-term activities which will foster CMM project development in M2M Partner countries. This grouping provides access to an international technical forum on CMM for China. While M2M lacks the impact of the flexible Kyoto mechanisms, it broadens opportunities for CMM technology transfer and China will benefit from participation.

CBM/CMM extraction, utilization technology and infrastructure

Australia

Gas is drained in advance of mining, generally using in-seam boreholes, and postdrained from conventional cross-measure boreholes and surface goaf boreholes. Directional, underground long hole drilling is in routine use in gassy coal mines, holes in excess of 1 km being placed regularly. Codes for outburst prevention have been established which are followed religiously. Methods of improving predrainage in low permeability seams to improve gas capture and reduce outburst risk are being developed using hydro-fraccing techniques. Drained CMM is sold as pipeline gas or used for power generation to supply the mine or the regional power grid. In Queensland, 25 percent of gas marketed is VCBM. Many existing and planned gas utilization projects involve use of combinations of CMM and CBM. Australia's CBM resource is some 275,000 PJ.

Advancement of CMM capture and use has been underpinned by government grant support to help Australia meet its internal targets for emission reductions. Advanced CMM utilization technology is being developed and demonstrated in Australia. The first full-scale demonstration of Megtec's *Vocsidiser*, a VAM oxidation device, will take place at BHP Billiton's Westcliffe colliery. The energy will be used to generate electricity with a steam turbine. Commonwealth Scientific Industrial Research Organisation (Australia) (CSIRO) is experimenting with a catalytic turbine and gas engine capable of burning 1 percent CH_4 in air. Research is also being directed at ways of extracting CBM economically without sterilizing valuable coal resources.

United States

Gas drainage in the United States is achieved mainly using surface and underground predrainage, supplemented where necessary by surface goaf drainage. Cross-measures drainage is little used due to the relatively shallow depth of most workings. Substantial improvements have been made in drainage efficiency, most drained gas is utilized and significant reductions have been made in GHG emissions (Table 5.2) helped by some gassy mine closures.

Most CMM usage in the United States, to date, has been offsite sales to pipeline. The existing gas pipeline infrastructure in the U.S. plays an important role in determining if and where pipeline sales are feasible. In the Eastern United States, the natural gas pipeline system is more extensive and is located closer to gassy coal mines than in the Western United States. In some instances, mines may need to construct a feeder pipeline to transport the CMM to the pipeline from the well head or from the gas upgrading/processing facility. Mines in the Western U.S. often have little, or no access, to pipelines and, thus, the option for pipeline sales is limited there, since building feeder pipelines would be cost-prohibitive. Unlike in Europe or China, typically in the U.S., large population centers are not located in close proximity to coal mines. Thus, in the absence of reasonably accessible long-distance pipelines, there are not readily accessible CH_4 markets near most mines.

There have been a limited number of onsite uses for CMM in the United States, including power generation, thermal coal drying and mine heating. The low rate of onsite usage is primarily due to the fact that natural gas prices have been relatively high and electricity prices have been relatively low. As a result, many mines find it more profitable to sell their gas to pipelines and buy the electricity they require. To meet the high quality gas required by pipelines (usually 95 percent or greater CH_4 with minimal contaminants), generally, only gas from wells drilled into virgin seams, in advance of mining, is suitable. If necessary, lower quality CMM (for example, goaf well gas) can be processed to remove contaminants. Both cryogenic gas processing and pressure swing adsorption are used to upgrade gas quality. Another technique used in the United States is blending goaf gas with VCBM. There are a few power projects currently in existence and planned at U.S. mines.

In the United States, flaring has been used at a closed mine but has not been implemented

Table 5.2: Improvement in U.S. CMM Drainage and Emissions Reductions

Year	Underground Coal Production (Mt)	Longwall Coal Production (Mt)	Net CMM Emissions (Mt CO_2 equivalent)	% CMM Drainage Efficiency
1990	385	154	82.2	32
2003	320	166	53.7	42

Source: U.S. Energy Information Administration, http://tonto.eia.doe.gov/FTPROOT/coal/tr0588.pdf; USEPA et al. (2005).

at active mines. The coal industry has expressed concerns about the safety of flaring due to the potential for the flame to propagate back down to the mine and cause an underground explosion, but have not attempted to address the issue, whereas in the United Kingdom, C trading incentives have created sufficient drive for the industry to pursue a safe flaring solution. CMM is also flared in Australia where safety concerns have been fully addressed and venting of drained gas is prohibited.

Optimization of pipeline infrastructure use in China

Mechanisms are needed which encourage construction of pipelines and use of their full capacity. Pipelines operate on the basis of either contract carriage or common carriage. The former involves a consumer purchasing firm capacity, which is paid for whether used or not. When no further space is available, a consumer must wait in line until an existing user relinquishes space, the capacity is expanded or a new pipeline built having signed up sufficient capacity commitments by consumers. For common carriage pipelines, there is no contracted allocation of capacity and consumers pay a composite fee with a fixed and a variable element. New capacity is constructed on the basis of anticipated demand and many distribution companies operate this way.

6. Conclusions and Recommendations

Conclusions

China has large resources of CBM and CMM and the government has plans to increase their extraction and utilization. However, these ambitions will not be achieved unless the barriers which are impeding current development are removed and effective policies introduced to promote investment.

Government targets for increased CMM extraction and utilization will not be approached unless CMM capture efficiency is increased, the quality of drained gas improved and more of the drained gas utilized. Having captured gas by drainage, every effort should be made to use or destroy the gas rather than simply vent it to atmosphere as this will invariably represent a lower cost GHG emission mitigation option than either a VAM solution or use of RE.

Attaining significant improvements in CMM capture, utilization and destruction will require a raft of measures to be implemented involving:

- Use of integrated surface and underground pre- and post-gas drainage methods, where geological and mining conditions are appropriate;
- Application of VAM technology (subject to successful full-scale demonstration) at gassy mines for supplementing gas utilization and destruction and, in particular, where geological conditions are not favorable for the design and implementation of high efficiency capture systems; and
- Use of safe, high technology flaring to destroy gas which is surplus to requirements, of inadequate quality for utilization or where utilization is not viable or yet to be constructed.

A large government budget for improving gas control in KSOCM, the emergence of new STIS (drilling) technology and stimulation by potential CDM financing has raised interest in both CBM and CMM extraction and utilization activities. China government financial support for improvements in gas control in KSOCM has noticeably accelerated implementation and expansion of CMM extraction systems, but utilization has not kept pace. In the absence of a firm climate strategy, there is no policy which encourages utilization and destruction of CMM.

Projected annual increases in coal production, a greater proportion of production from longwall operations and an expectation of increasing gas drainage capacities and performance will lead to increasing volumes of CMM availability. By 2010, some 3.6 Bm^3 drained CH_4 could be available for utilization in China, if action is taken as recommended in this report compared with the more ambitious government target of 5 Bm^3; emissions reduction of up to 54 Mt CO_2 equivalent should, therefore, be possible. Failure to act will limit the potentially usable CMM to only 1.2 Bm^3. Further reductions in CMM emissions will be out of reach unless, in addition to necessary improvements at the major gassy mines, radical action is taken to deal with the many small sources by subsidizing construction of new drainage plants, improving existing plants, raising capture efficiency and installing flare systems at a large number of nonKSOCMs. At present, the NDRC will not approve the use of flares solely or in conjunction with CMM utilization projects at coal mines under the CDM. Consequently, large volumes of drained but unused CH_4 are vented to atmosphere rather than destroyed at low cost. Low CH_4 concentrations in drained gas at many mines are limiting the potential for legal CMM utilization and are a manifestation of inappropriate gas drainage design and management. More than 18 Bm^3 of VAM, equivalent to 271 Mt CO_2, could be exhausted to the atmosphere in 2010, but only a small proportion is likely to be used.

The advent of new STIS-guided drilling technologies which have the potential to facilitate commercial VCBM production from coalfields, hitherto considered uneconomic, seems to be driving a renaissance. Provided this new technology can be demonstrated to deliver promised results, a strong CBM industry is assured in China. Startling achievements will not be achieved immediately and there will be a period of mixed results while the technology is evolved to suit geological conditions in China, and the necessary skills and experience are gained by the service companies. There will still be a role for properly designed and completed vertical, hydro-fractured wells in some coalfield areas. CBM production from surface wells could reach 1.8 Bm^3 by 2010 although success with STIS could increase the yield substantially. Most of this production is likely to be concentrated in Shanxi province.

The Government of China's strategy plan for promoting CBM & CMM extraction and utilization involves attracting more investment, guiding the selection of CBM/CMM development areas, building a commercial base of CBM/CMM in three years and, at the same time, developing new resources in some areas such as Yunan and Heilongjiang provinces. The ultimate aim is to improve coal mine safety, but how this will be achieved is uncertain due to conflicting regulations and activities. A lack of pipeline infrastructure, the immature gas market and the underdeveloped economy of methane-intensive areas are three major factors which need to be addressed in developing China's CBM and CMM industry and to attract the necessary investment in CBM development. However, these objectives will not be achievable without policy incentives.

Recommendations

Effective action to reduce CH_4 emissions from coal mines and to better exploit the naturally occurring gases in coal seams will require a combination of measures from formulation of climate change strategy, through policy development, continuing institutional reform, introduction of market-based incentives and capacity-building. Successful GHG emission reduction drivers in other countries, Australia for example, operate in a market environment which China aspires to develop, but is still some way off from achieving. More rapid development of CBM and CMM resources can be achieved if the Government of China continues regulatory reforms and further liberalizing of energy markets.

The key areas requiring further attention and actions by the Government of China in which the international community, including the World Bank, could assist, are summarized below:

Government policy, legal and regulatory framework

CMM priorities and strategy should be redefined with reduction of CMM emissions being the highest priority focus.

China will continue to rely heavily on coal as a primary energy source for the foreseeable future and CMM emissions will represent a significant proportion of the country's GHG emissions. Under its Kyoto commitment, China is obliged to develop a climate change response and reduction of coal-related emissions will be a key element.

Policies aimed at reducing GHG emissions from coal mines will automatically result in improvements in safety and greater use of CMM for energy purposes provided international safety standards are a prerequisite for compliance. The CDM has proved the most successful driver of CMM exploitation to date in China, but there are government-imposed barriers preventing more effective implementation. In particular, Chinese enterprises are not permitted to enter into CER-sharing agreements. This has removed a powerful means of securing project investment and has alarmed investors, reawakening concerns about lack of sanctity in agreements made by State-Owned Enterprises (SOEs). The incentive for project investors to provide continuing assistance throughout a project to ensure delivery of CERs is removed. Reluctance to accept flaring of surplus and unusable CMM also narrows the applicability of CDM. The government is concerned that as flaring is the lowest cost destruction option, gas would be indiscriminately flared and wasted as an energy source. However, such effects can be countered using fiscal and regulatory measures. The current philosophy which accepts venting as the only alternative to utilization is inconsistent with the aims of the UNFCCC. Unless these impediments are removed, CMM emission reduction and energy recovery targets will not be achieved.

The following measures would ensure that CMM is utilized, wherever practical and feasible, and the surplus destroyed:

- Government strategy to minimize GHG emissions from its mines implemented through policies which encourage optimum use and maximum destruction of CH_4;
- Policy incentives which encourage surplus drained gas to be flared, as is done in Australia and the United Kingdom, rather than vented to the atmosphere;
- A higher government levy on CERs generated by flaring to offset the lower mitigation cost of flaring compared with utilization;
- Fiscal incentives against equipment and construction costs for all GHG mitigation schemes; and
- Strongly enforced mine safety standards requiring drained gas to be of a specified minimum purity ($\geq$30 percent) for utilization to encourage mines to improve gas drainage standards and performance, capture more usable gas and become safer workplaces.

In order to formulate and implement effective strategy, the full scale of the problem must be determined by preparing a reliable and complete CMM emissions inventory.

The quantities of CH_4 emitted from China's coal mines are not known to any degree of accuracy (IPCC Tier 1 method) and the data are incomplete as they are based on the KSOCM which represent only about half of China's coal production. Without these data, the full potential for scale-up cannot be properly assessed and effective management of China's CMM resources and emissions established. For example, a survey of county, village and privately-owned mines in the highly gassy Jincheng mining area revealed that in producing 9.6 Mt of coal, some 332 Mm^3 of CH_4 was drained, of which about 20 percent was utilized. The potentially drainable CMM resource in China achievable using tried and tested technology is currently so large that treatment of mine ventilation air, which carries an even larger CH_4 resource, has not yet attracted much attention. However, this situation could change rapidly in the light of technological developments and the availability of CDM financing for VAM utilization projects.

It is, therefore, recommended that:

- An IPCC Tier 3 methodology is developed and applied to all the KSOCM and a survey undertaken to establish reliable Tier 1 estimators for the remainder of the coal mining sector; and
- An inventory should include CH_4 flows and concentrations in exhaust ventilation shafts (VAM).

Safety legislation should be extended to pave the way for utilization and destruction of VAM.

VAM represents a significant emission and potential energy source as more than 70 percent of the CH_4 released from coal mines is exhausted at low concentrations. Technologies for removing and using low concentrations of CH_4 in ventilation air are being developed but these will be costly requiring CDM support for viability and new mine safety legislation to allow for safe use or destruction of CH_4 at concentrations below the lower explosive limit at a designated factor of safety. China will become a major target for CDM-financed VAM schemes once a suitable technology is proven and this will lead to major reductions in emissions.

It is recommended that:

- Safety legislation should be revised to allow the use and destruction of low concentration VAM subject to stringent safety precautions and a maximum permissible CH_4 concentration which must not be exceeded to ensure a high factor of safety.

CBM remains in coal seams until extracted at a production borehole or disturbed by mining. Gas removed from coal seams ahead of mining, or in areas which are unlikely to be mined for some time, reduce the future threat to the environment but, more importantly, provide a valuable source of energy comparable to conventional natural gas. Institutional and regulatory reforms are needed to establish fairer, competitive and more effective CBM resource management to ensure this clean energy is to be more effectively exploited.

CBM resource management in China involves a carve-up of potential prospective areas between the State-owned petroleum and CUCBM monopolies. Resource is managed by those with vested interests in the proceeds of development rather than by an independent government body serving the national interest. Foreign CBM developers are required to sign an agreement, or PSC, with CUCBM which sets out the rules, a minimum exploration expenditure and other conditions. However, PSCs are not sacrosanct and there is evidence that state-owned oil and gas companies have disregarded the "license" boundaries in their exploration programs. The PSCs have no formal legislative standing but are intended to provide an internationally recognized form of cooperative agreement and a basis for negotiation.

At present, CUCBM and other SOEs with CBM exploration interests (for example, Petrochina) apply to MoLaR for CBM exploration and development licenses which are issued on a first come, first served basis, unless the area is reserved for other purposes. CUCBM can decide whether to explore alone or to form a cooperative venture with a foreign company under a PSC. The current licensing system does not allow for any market competition, licenses can be easily extended and there is no incentive to expedite exploration and development. As a result, exploration is inefficient and development slow. Substantial CBM license areas have been let but not explored due to lack of resource, or ranked as of low interest by the holder. Some developers have sought to build large portfolios of license areas for which they have neither the intention nor the resources to explore and develop merely to try and impress investors. Access to both coal and large associated CH_4 resources are also sterilized by coal mine leases of 70 years or more which hinder and slow development.

The formation of CUCBM as a regulator to protect the interests of China was an essential first step in establishing a CBM industry in China and CUCBM has played an important role in managing foreign involvement and investment in CBM exploration. However, administrative and regulatory needs have now changed and it is recommended that:

- CUCBM should be divested of its monopoly privileges and allowed to operate as a commercial exploration and development entity;

- The role of CBM regulator should be passed to MoLaR or a new Energy Ministry – and CBM expertise built within the appointed department;

- A more open, competitive and transparent bidding process for CBM blocks is introduced;

- The CBM industry should be integrated into the natural gas and petroleum industry due to overlapping interests, but leaving CMM firmly in the coal mining sector;

- An effective regulatory system should be devised for managing the interaction between CBM and coal mining interests. Both Australia and the United Kingdom have established robust schemes which could be adapted for China;

- PSCs should be underpinned by legislation, and exploration and development license boundaries enforced. Licensing terms should be more stringent and strictly enforced. CBM license areas which do not receive the requisite exploration attention within a defined time period, not exceeding three years, should be relinquished and bids invited from qualified companies;

- The costs of holding license blocks should be increased to speed relinquishing of areas which the developer has discarded or has insufficient resources to explore;

- Any qualified Chinese company should be free to enter into a PSC agreement with a foreign company, but the terms should be subject to oversight by an independent regulatory commission; and

- Licensing of coal should be separated from the licensing of CBM rights. Mines currently with CBM interests should be required to make exploration and development commitments similar to those expected of PSC holders or relinquish title to the gas. To prevent loss of coal reserves, a legally binding interaction agreement should be introduced.

The institutional and legal framework should be rationalized and strengthened.

Both coal and mineral resources laws are currently being revised, but independent of each other. The revisions should be examined in detail before promulgation and any conflicts resolved. In reviewing the coal law, efforts should be made to identify the reasons for its inadequacy in addressing safety issues, in particular gas drainage in coal mines, and also ensure there is no conflict with the government aims of promoting increased CMM extraction and utilization. Mine safety laws are all too often flouted and revisions will only have an impact if enforcement is strengthened. Now would be an opportune time to strengthen the legal framework of the coal mining sector and, in particular, address CBM/CMM safety and interactive issues.

CBM extracted independent of mining is a natural gas production operation. CBM reservoirs are difficult and costly to develop in relation to their production potential compared with conventional natural gas reservoirs, and government policy should be aimed at encouraging the natural gas industry to develop those marginal resources most likely to be of maximum future commercial and strategic benefit. It is difficult for the fledgling CBM industry to compete with the petroleum industry for investment due to its high risk and current lack of scale. The situation is exacerbated by its separation from the petroleum sector and alignment with the coal industry. The State's investment in CBM exploration is only 0.02 of that spent on oil and natural gas exploration despite its official ranking as a potential major energy resource. In contrast, CMM is an unavoidable by-product of mining with serious environmental and safety impacts to be considered in addition to its energy potential.

It is, therefore, recommended that:

- The revisions of the Coal and Mineral Resources Laws are examined and compared in detail and any conflicts resolved before promulgation. In reviewing the Coal Law, efforts should be made to identify the reasons for its inadequacy in addressing safety issues, in particular underground gas drainage, and also ensure there is no conflict with the government aims of promoting increased CMM extraction and utilization;
- CBM should be grouped and managed along with other difficult natural gas sources such as tight sands, which should be subject to similar incentives; and
- CMM should remain firmly in the mining sector under provincial control with central government oversight.

Improving CMM availability and quality

Capacity-building is needed to fill serious knowledge and technology gaps at coal mines.

Investment in CH_4 drainage equipment and technology without an understanding of its applicability is leading to wastage, and expected reductions in numbers and severity of accidents and increased gas availability for utilization are not being achieved. The variable, and often low quality of drained gas, is a limitation to efficient utilization, which must be tackled within the mining operations. Major technical issues which need to be addressed include poor sealing of underground gas drainage boreholes, inadequate design, monitoring and management of gas drainage systems and use of drainage methods unsuited to the geological and mining conditions. Coal mine management in KSOCM has too little scope to make technical changes and improvements on the basis of their firsthand experience where mining groups dictate gas control and gas drainage methods to be employed at their mines. The designs must be approved by qualified design institutes and these, and any other changes, invariably have to be approved by referring to higher levels within the mining group and, in some instances, to provincial government as safety liability extends to vice governor level.

In order to improve CMM capture and quality, coal mine staff need direct access to more detailed information, knowledge and technology relating to gas emission prediction, ventilation planning, gas drainage methods, equipment, monitoring and CMM utilization and destruction options. Coal mining companies need such improved capabilities if they are to be able to assist local CMM project developers to analyze project risk and present properly detailed financial arguments to attract external investment. Foreign companies actively seeking CMM investment projects invariably find the amount of information provided by Chinese coal mining companies is inadequate and insufficiently detailed. Mining enterprises seeking to promote their projects need to prepare detailed plans and studies and provide the necessary supporting data.

Implementation of an effective emissions reduction strategy for coal mines will require application of combinations of surface CBM, underground CMM and emerging VAM utilization technologies, the choice depending on site-specific characteristics and the necessary capacity-building, and technology transfer can be achieved with the help of a carefully designed and managed demonstration project. Analysis of the range of gas use options should also be examined in a demonstration project to show cost-effective exploitation of the gas having considered the quantity and value of high purity CBM available relative to the generally larger quantities of variable low to medium quality CMM, domestic and industrial thermal demand, power generation, chemical and vehicle use and transport infrastructure (pipeline) requirements and costs.

Coal mining companies are also in need of support with CDM projects to deliver CERs, but the needed professional service support industry capabilities do not presently exist. Without this support, CDM projects at mines will underperform substantially, the C assets market will lose confidence in the sector and government CMM utilization targets will be unachievable.

New, fully mechanized private and locally-owned mines in gassy areas are starting to recognize the potential benefits of CMM utilization, but this sector of the coal mining industry, which is likely to grow in importance, does not presently receive the attention it needs.

It, is, therefore recommended that:

- New fully mechanized private and locally-owned mines be included in any new CMM promotional initiative; and
- Capacity-building be provided:
  - To government advisers and planners, mine designers, technical staff and mine management to help them better understand the current state-of-the-art, its limitations and the fundamental principles of gas drainage and control;
  - To coal mining companies so that they are able to assist local CMM project developers to analyze project risk and present properly detailed financial arguments to attract external investment;
  - To professional service support companies so that they can help coal mines with CDM projects to deliver CERs; and
  - Through a CMM demonstration project at a selected coal mine of optimization of energy recovery and maximization of CH_4 destruction to international safety standards. The CDM or the United Nations Economic Commission for Europe (UNECE), through the GEF program for financing energy efficiency and renewable investments for climate change, should be investigated as financing sources.

Strong incentives are needed to vigorously drive change

The government should further stimulate investment in CMM utilization and destruction. Existing tax benefits in China have not been effective by themselves and CDM alone will not be sufficient to stimulate the level of investment required to achieve the government's goals. Additional incentives are needed which will encourage greater levels of both domestic and international investment in CMM utilization and destruction.

A possible route is exemplified by China's Renewable Energy Law which took effect on January 1, 2006, introducing a pricing mechanism which ensures a premium over the lowest cost clean coal option and includes a government subsidy. This incentive would be particularly cost-effective if applied to CMM as the incremental cost of power generation using CMM is substantially lower than that of wind generated power. Surface CBM extraction, connected with active mining, which results in avoidance of CH_4 emissions, should be treated as CMM insofar as incentives are concerned.

Gas abatement certificates modeled on the New South Wales scheme have attractions as part of an in-country GHG trading system but could not be introduced until a national trading scheme was established. Nevertheless, as China's GHG emissions will continue to grow, such an approach has merit as part of a long-term strategy. A more rapid response could be achieved with grant schemes similar to those developed in Australia which have successfully encouraged demonstration of new and innovative CMM utilization technologies. Projects should be selected on merit and grants only made available for properly designed, peer reviewed projects with a high chance of success and not used to subsidize ill-conceived, replicated projects by coal mining SOEs as has happened too often in the past. The government could partner with GEF to foster such a scheme.

Domestic mining companies can benefit from exercising greater corporate environmental responsibility as well as assisting the government achieve its strategic aims. Domestic coal mining companies can reduce GHG emissions without detriment to their business, especially if encouraged by market-based and grant incentives as can be demonstrated in Australia where innovation, R&D in CMM extraction and use are enabling increasingly effective results to be achieved thus reducing long-term business and reputation risk to major companies. Spin-off benefits which directly benefit financial performance include improved gas control at the coalface, safer working conditions, a local low-cost energy supply and reduced mine operating costs. The organizational structures of China's large mining groups (former KSOCM) mean that action will require the sanction of provincial governments but that should not deter a bottom-up initiative.

R&D is needed to enhance understanding of the characteristics of coal seam gas reservoirs in Chinese geological conditions and to explore the use of STIS (drilling) technologies developed in Australia and the United States for extracting gas from virgin coal seams with marginal permeability. These advanced STIS drilling techniques could also have a role for enhancing mine safety by improving the effectiveness of both pre- and post-gas drainage methods. Wider application of advanced gas extraction and capture technologies are essential if China is to scale up its CBM/CMM industry.

China would benefit from easier access to imported gas control technology for its mines and CMM utilization schemes. However, some foreign companies with key technologies are reluctant to enter the China market due to lack of protection of IPR, cost and risk of market entry, protracted approvals procedures for underground equipment (but now being improved), competition with low-cost Chinese equipment and lack of transparency in bidding for tenders.

It is recommended that:

- CMM is treated similarly to RE in China and enjoys a similar level of subsidy, as is the case in Germany;
- Grant schemes similar to those used successfully in Australia should be introduced to encourage demonstration of new and innovative CMM utilization technologies;
- Incentives to stimulate investment in CMM extraction and utilization and CH_4 emission reductions should be aimed at coal mines of all types. In particular, financing arrangements and loan facilities should be made available through local, commercial banks to facilitate development of small-scale CMM utilization schemes by local enterprises;
- Key State-owned mines, in particular the large coal mining enterprises with international expansion aspirations, should be aware of the importance of protecting reputation with regard to environmental protection and should develop corporate policies which seek to maximize benefits from available GHG emission reduction incentives and set emission reduction targets;

- Targeted R&D of CBM and CMM extraction technology should be expanded;

- Government should create policy incentives to encourage foreign service companies and JVs with the skills and experience to introduce, adapt and exploit new and advanced CBM CMM technologies in China; and

- Barriers to importation of key technologies should be removed by recognizing international safety testing standards for certification of underground equipment, rigorous enforcement of patent and IPR protection and ensuring transparent and competitive bidding for tenders.

Regional development strategies

An effective emissions reduction strategy must recognize regional differences. For example, development of CMM utilization projects in the coal-rich Shanxi province should be a priority and would be much more cost-effective than RE. Where such conditions exist, CBM/CMM development should be afforded special status.

CH_4 extraction and utilization from coal seams in economically underdeveloped coalfield areas will benefit local communities and provide energy for displacing use of polluting coal in local, small-scale enterprises.

Rational development of CBM requires juxtaposition of market, gas transport infrastructure and geologically favorable conditions for commercial extraction, all of which are present to some extent in Shanxi province. However, in Shanxi, as in other coal-rich provinces, there is insufficient cohesion between the planning of CBM, CMM and natural gas transport and utilization projects.

Shanxi merits special attention as a model province for developing, implementing and evaluating policy and action programs to optimize the economic and environmental benefits of CBM and CMM exploitation. The choice of Shanxi as a special case is justified by it being a major coal-producing province with arguably the largest potential CMM reserves, the most promising CBM prospect areas (E. Ordos and S. Qinshui coal basins), a strong demand for clean energy to facilitate air quality improvements in its industrial cities crossed by major natural gas pipelines and committed to constructing a provincial gas pipeline infrastructure and increasing the gas component in the energy mix.

Construction of an accessible pipeline infrastructure by the government in selected areas will stimulate exploration and development of CBM and CMM (by analogy with road construction as an economic development stimulant to isolated communities). For example, in the Raton Basin in the United States, the lack of pipeline connections stalled CBM development for more than 20 years. A system of contract carriage, which allows an operator to contract a fixed transmission capacity, whether used or not, would reduce construction risk, allow multiple party access and ensure maximum use of available capacity. Such an approach has been adopted in most countries with newly developing gas industries and it is also applied by gas transmission companies in the United States. However, usual practice in China is to adopt common carriage[5] and it is not unusual for CMM pipelines to be operated well below design capacities.

It is recommended that:

- The Shanxi provincial government should develop an integrated development plan and

[5] *For common carriage pipelines, there is no contracted allocation of capacity and consumer pay a composite fee with a fixed and a variable element.*

policy framework to help it meet its aspirations of a commercial and sustainable CBM/CMM industry;

- Grant assistance is given to constructing gas distribution infrastructure in special status areas and coal-to-gas switching incentives offered to consumers; but price subsidy should be avoided as this will lead to market inefficiencies; and
- All parties should be able to compete openly for access to gas pipelines and enter into contracts for transmission capacity to reduce the exploration and development risk.

Annex I

CMM Extraction from KSOCM in China (1980-2002)

Mining Group	Province	Annual CH_4 recovery, Mm^3						
		1980	1985	1990	1995	1998	2000	2002
Fushun	Liaoning	100	102	108	122	127	129	128
Yangquan	Shanxi	86	90	77	93	115	117	200
Songzao	Chongqing	11	34	59	56	70	76	93
Tianfu	Chongqing	5	13	23	27	26	77	17
Nantong	Chongqing	2	7	22	21	28	23	15
Zhongliangshan	Chongqing	19	19	22	21	24	24	24
Furong	Sichuan	1	1	12	27	29	25	38
Liuzhi	Guizhou	12	5	11	20	19	8	7
Jiaozuo	Henan	2	4	10	14	12	10	11
Tiefa	Liaoning	3	2	10	22	36	44	64
Kailuan	Hebei	3	4	8	9	16	9	9
Fengcheng	Jiangxi	10	5	8	9	6	10	3
Fengfeng	Hebei	5	6	8	14	14	11	15
Hebi	Henan	5	7	7	10	11	12	12
Beipaio	Liaoning	4	2	6	4	5	3	–
Panjiang	Guizhou	–	–	6	21	36	102	71
Jixi	Heilongjiang	2	7	5	2	–	–	0.7
Shuicheng	Guizhou	2	2	5	19	12	26	59
Baotou	Inner Mongolia	18	4	5	-	2	5	4
Huainan	Anhui	2	5	4	5	23	49	112
Hegang	Heilongjiang	3	1	4	6	4	10	12

Mining Group	Province	Annual CH_4 recovery, Mm^3						
		1980	1985	1990	1995	1998	2000	2002
Guzhuang	Shanxi	–	1	4	3	–	–	–
Yingying	Shanxi	3	1	4	4	1	–	–
Huaibei	Anhui	2	4	3	5	8	18	43
Xishan	Shanxi	1	–	1	6	3	3	9
Lianshao	Hunan	–	2	1	2	3	3	3
Pingxiang	Jiangxi	–	1	–	1	4	3	2
Liaoyuan	Jilin	2	1	–	4	8	12	5
Shenyang	Liaoning	–	–	–	2	5	9	26
Shitanjing	Ningxia	–	–	–	15	28	44	–
Yinggangling	Jiangxi	–	–	–	–	1	1	1
Baisha	Hunan	–	–	–	–	1	1	1
Guangwang	Sichuan	–	–	–	1	2	3	1
Yongrong	Sichuan	–	–	–	2	3	3	5
Shizuishan	Ningxia	–	–	–	1	2	6	–
Tongchuan	Shaanxi	–	–	–	6	7	4	7
Hancheng	Shaanxi	–	–	–	1	3	4	3
Jingyuan	Gansu	–	–	–	4	5	5	7
Yaojie	Gansu	–	–	–	–	–	1	1
Pingdingshan	Henan	–	–	–	3	25	26	28
Nanzhuang	Shanxi	–	–	–	12	1	–	–
Meitian	Guangdong	–	–	–	2	–	–	–
Total[1]		293	330	434	600	742	918	1146

Source: CCII, 2003 published in DTI (2004).

1. Using nonrounded data.

Annex II

Comparative Investment Costs US$/t CO_2 Equivalent Annual Emission Destruction or Avoidance Capacity

Data Used in Calculations

Basis for comparison 1 MWyear (electricity)

Heating value of CMM = 34.6 MJ/m^3 (pure basis)

Heating value of coal = 29.3 GJ/t

Combined grid emission factor = 0.98 t CO_2/MWh

CO_2 emission factor for gas combustion 0.869

Coal power plant electricity conversion efficiency of 35 percent

CMM power plant electricity conversion efficiency of 37 percent (net)

Annual CMM power plant availability of 7,500 h (85 percent)

Flare availability of 7,500 h (85 percent)

CH_4 concentration of flared gas = 30 percent

Wind turbine availability of 3,500 h (40 percent used and average is around 30 percent)

Methane destruction in a CMM Power plant

A medium-scale CMM power plant in China costs about US$0.94 million/MW generating capacity.

1 MWh (3.6 GJ) is generated using (3,600/34.6)/0.37 = 281.2m^3 CMM (pure)

Annual consumption = 7,500 x 281.2 = 2.11 Mm^3 CMM (pure)

The investment cost per ton annual capacity CO_2 avoided = (0.94M/2.11M) x 66.4 x (1/0.869) = US$34.0/t CO_2 equivalent (net)

CMM destruction by flaring

An imported, high efficiency, low emission ground flare adapted for safe use at coal mines with a capacity of 2,000m^3/h gas mixture costs US$0.18 million.

Over a year, the flare can destroy 7,500 x 2,000 x 0.3m^3 = 4.5 Mm^3 CMM (pure basis)

The investment cost per ton annual capacity CO_2 avoided = (0.18M/4.5M) x 66.4 x (1/0.869) = US$3.06/t CO_2 (net)

Adjusted to a common comparison basis with the CMM power plant of 2.11 Mm^3 CMM (pure), the capital cost of the flare unit would be unchanged (accommodated within the downturn of the same specification equipment) and the investment cost per ton CO_2 annual destruction capacity = US$6.5/t CO_2 equivalent (net)

Note that the capital cost would reduce substantially with the introduction of locally manufactured flare units.

CMM and CO_2 emissions displaced by wind energy

1 MW grid-connected wind power generation capacity costs from US$1.00 million-US$1.26 million in China depending on scale (IT Power, CNE)

1 MWh wind generation capacity displaces (3.6/29.3)/0.35 = 0.35 t coal combustion

Assuming an average relative emission at the coal mine of 10 m^3/t (typical of many Chinese mines) 0.35 t coal can release 3.5 m^3 CH_4 which is equivalent to 0.053 t CO_2

The displaced CO_2 from coal combustion is 0.98 t and, therefore, the total CO_2 offset = 0.98 + 0.053 = 1.03 t/MWh

The annual emission avoidance = 3,500 x 1.03 = 3,605 t CO_2 equivalent

The investment cost per ton annual capacity CO_2 avoided = US$277-US$350/t CO_2

Annex III

CBM/CMM Extraction and Utilization Technology

CBM Technology Issues

Vertical CBM production wells

CBM often does not flow readily from a coal seam into a vertical borehole until the coal has been stimulated using hydraulic fracturing. This method involves inducing a vertical fracture (ideally) in the strata by the injection of liquid under pressure, typically water. Sand, or some other material (proppant), is used to keep the fractures open to allow free passage of gas and water once the injection pressure is released. The fracture forms a path of high conductivity along which gas can flow freely into the well bore. The flow through the natural fracture network in the coal becomes the limiting production factor. The ability of coal seams to transmit CH_4 is determined by natural factors, the cleat or fracture density, cleat transmissivity, the degree of water saturation and the fluid pressure in the cleat. The preservation of fracture permeability depends on the structural history of the coal basin.

Alternative methods of completing vertical boreholes have been developed but are of little general relevance to China.

Surface to In-seam Boreholes

STIS (drilling) methods involve drilling surface to horizontal in-seam boreholes, with clean underbalanced fluids. This technology provides a larger area of contact between the production borehole and the coal seam than can be achieved in a fracced (hydraulically fractured) vertical borehole. Thus, commercial flows can be obtained from lower permeability coals than could be achieved previously. The need for fraccing is obviated and the chance of damaging coal permeability is reduced.

The advantages of draining gas from the surface include ease of access to any part of the working area, reduced interference with mining activities, fewer men underground and less underground drainage infrastructure to install, maintain and monitor. By using STIS, any surface environmental restrictions can generally be avoided and there is no risk of damage to roof strata as is the case with fraccing. The disadvantages of surface drilling are high cost and the possible risk of water inrush through failure to seal off aquifers or seal boreholes on abandonment.

Effective application of STIS will require specialist contractors and equipment in addition to development trials to adapt the technology to Chinese geological conditions. Underground long hole in-seam drilling has proved difficult in some coalfields and similar problems could beset STIS (drilling) in some coalfield areas. However, this technology has shown promise when applied to the south Qinshui basin in southern Shanxi, an area which has also proved favorable for underground long hole drilling.

Surface to in-seam guided drilling offers the following benefits:

- A borehole can be steered to intersect the dominant fracture system of the coal, thus commercial production may be achievable from marginal permeability coals if sufficient fractures are intercepted;
- Large surface area contact with the coal production zone and clean drilling obviates the need for fraccing;
- Multiple branched holes can be drilled from a single, convenient surface location;
- Multiple wells can be drilled from a single pad, thus reducing the costs of access, drilling and gas gathering; and
- Improved mine safety when used for predrainage of coal seams ahead of mining.

Guided drilling technologies have been used successfully for many years within the oil and gas industry. Advancements in down-hole measurement and communications technology coupled with ability to locate guidance sensors directly behind the drill bit, has resulted in the development of a new generation of guided drilling equipment capable of providing greater accuracy, increased drilling speeds and cleaner hole completions. Elaborate drilling patterns have been evolved for CBM development but they are not always designed to exploit the coal seam reservoir characteristics to maximum advantage. Australian experience of developing relatively low permeability CBM projects is particularly relevant to China. Australian companies are taking an increasing interest in China's CBM industry and their involvement, experience and pragmatism should help to accelerate CBM activity in the most promising coalfield areas.

STIS wells have been drilled in the Shouyang block near Taiyuan, eastern Ordos and south Qinshui, all in Shanxi province. Initial reports are encouraging although some experts believe that the full potential has yet to be realized as the necessary radius drilling and steering skills will take time to learn.

Enhanced CBM (ECBM)

Methods of enhancing the recovery of methane from virgin coal seams are being studied and developed in the United States, Canada and the European Union (EU).

The basic approach involves injecting CO_2, Nitrogen (N_2) or a combination of these gases into a deep coal seam. CO_2 is preferentially adsorbed onto coal, freeing CG_4 for transport to the production well. An important advantage of this mechanism is that it also results in sequestration of CO_2, desirable because CO_2 is the largest anthropogenic contributor to global warming. However, CO_2 sequestration would sterilize coal resources as any future mining would rerelease the gas back into the atmosphere.

Injection of N_2 into a productive coal seam lowers the partial pressure of CH_4 allowing CH_4 to desorb from the coal matrix. In practice, the recovery gains may be due more to flushing of the CBM into the production wells rather than as a result of desorption effects. Preparing and injecting pure gases is costly. Flue gas from a power plant, consisting of a mixture of N_2 and CO_2 with some impurities, could provide a low-cost alternative. However, the problems of low permeability which hinder CBM production from surface wells would similarly inhibit rates of CO_2 or N_2 injection. The benefits of enhanced recovery will, therefore, be largely gained in relatively permeable seams by extending the life of production fields. In China, a high proportion of these seams are mining targets, so, there will be no net sequestration benefit.

CMM drainage technology status

A survey of perceived underground gas drainage problems was undertaken in 2003 by sending questionnaires to coal mining groups (Creedy and Garner, 2004). Detailed replies were obtained from 16 of the groups, largely representing the areas with the gassiest mines (Table A3.1). The study revealed that gas drainage performance is often hampered by inadequate drilling equipment. Lack of monitoring and control facilities also hinders CH_4 control in the mine environment and results in quality variations in drained gas. Analysis shows inadequate and ineffective management lies at the root of many problems with difficulties compounded by poor equipment, insufficient measurement and monitoring facilities and a lack of technical knowledge of emission and gas control processes among some practitioners.

Key statistics on gas control and gas drainage practice in China from the year 2000 imply low serviceability of equipment and poor drainage performance:

- Seven hundred and Ninety three drill rigs reported although only 452 in use;
- Six hundred and forty seven CH_4 drainage pumps reported although only 383 in use;
- 0.4 m of drainage borehole drilled per ton of coal;
- 32 percent average drained gas concentration; and
- 22.5 percent average gas drainage efficiency.

Table A3.1: Survey of Gas Drainage Problems

Perceived problem	Survey Result %
Drilling Difficulties	14
Inadequate Monitoring	19
Poor Performance	33
Low Use of Gas	12
Lack of Funds	21

Predrainage

Many mines in China work thick seams some of which have high content and others are outburst-prone. Predrainage offers a means of reducing the gas content of the seam and reducing the potential gas hazard prior to working, but is often difficult to implement. Of particular interest in this respect is long hole drilling technology. The Asian American Company Inc. (AACI) successfully drills long in-seam degassing boreholes at Daning mine near Jincheng. Jincheng Coal Mining Group has also reported success with in-seam drilling at Sihe mine. Daning and Sihe mines are working a thick coal seam in the South Qinshui coalfield which has a well-developed fracture system which lends itself to predrainage. However, similar geological conditions and coal characteristics are not found elsewhere in China and, therefore, the advanced drilling technology may not be transferable to other coalfields.

Effective predrainage is difficult to achieve in the low permeability coals found in many parts of China, and, in the absence of an outburst risk, it is of little benefit as a safety measure. Both U.S. and Australian contractors experienced difficulties in trying to drill a long in-seam borehole at Songzao. Long hole in-seam drilling using imported drilling equipment also failed at Fushun, Pingdingshan and Huainan due to problems with soft coal and high stresses. There is a clear need to examine the drilling systems and technology in use in China and to question whether predrainage gas control solutions currently being considered are appropriate to the geological and mining conditions. Difficulties in underground drilling indicate the challenges to application of STIS (drilling) methods.

Heavy investment by the central government and mining groups over the last two years in gas control should have resulted in some improvements, but there are no recent statistical data available to confirm this.

Gas flow monitoring

SAWS are keen to encourage use of advanced foreign equipment, but foreign mining electrical equipment safety approvals are not recognized which leads to delays while imported equipment undergoes the testing and acceptance procedures.

Safety equipment and systems are often installed underground with limited provision being made for preventative maintenance. Too little use is made of monitoring data for forestalling and preventing gas problems and optimizing flow and purity. Recorded monitoring data attract most interest after an incident when it can be used to assist an investigation into cause and blame.

Gas monitoring systems at CH_4 extraction stations are not always reliable which could compromise utilization operations as well as safety. Typical problems include failed detectors, inappropriate placement of gas detectors and inaccurate volume flow calculation methods.

Floor gas drainage

Cross-measures drilling in the roof for gas drainage is accepted technology, but mine engineers in China often consider the drilling of floor gas drainage boreholes as problematic due to difficulties in clearing cuttings. This implies the drilling equipment or drilling systems are ineffective. There are significant coal seam sources in the floor of many Chinese longwalls and technology is needed to enable this gas to be tapped more effectively, especially where there is a risk of sudden emissions from the floor.

Sealing gas drainage boreholes to prevent air leakage

CH_4 drainage systems should exert suction on the surrounding strata to draw gas into the pipework. An effective seal is needed between the borehole and its collar to prevent air being drawn in. The conventional approach is to cement a steel or GRP standpipe into place through which drilling is continued. The standpipe length must pass through the highly fractured zone adjoining the roadway. Generally, gas drainage boreholes are inadequately sealed in Chinese mines. Once suction is applied, air leakage is inevitable leading to poor capture performance and low purity gas.

There is considerable scope for increasing the availability and quality of gas drained from coal mines but more investment is needed in training, exploiting monitoring data, refining drainage methods, modern underground drilling equipment and the building of management capacity to exploit these systems to maximum benefit. The problem of maintaining CH_4 purity is a significant factor limiting gas use and this issue requires further examination.

A possible new postdrainage technology (CMM)

Attention has been focused on applying STIS for commercial CBM production and for predrainage to reduce gas emission risks in coal mines. However, there is another application that has yet to be demonstrated in China. Gas drainage galleries driven in the roof of a longwall panel have proved effective for capturing gas released by mining. A potential low-cost alternative of drilling guided long holes from underground above a longwall panel was demonstrated by specialist contractors but has not been replicated. A further option is to use STIS to install postdrainage long holes above longwall panels. Postdrainage activity could be moved outside the mine, but the costs need close examination to determine the depths at which application may be appropriate. Potentially additional benefits to the mine could be consistently higher gas capture and more gas for utilization. Super-adjacent STIS drainage is likely to be more cost-effective than surface goaf drainage as fewer vertical drilled sections will be required and gas flows and quality should be higher.

Variability of CMM Flow

The design of a suitable utilization scheme using CMM depends on the supply and quality of the gas and the variability of these parameters. The flow of usable CMM depends on:

- Geology and seam gas contents;
- Method of mining;
- Effects of previous mining;
- Current and future rates of coal extraction;
- Gas capture performance; and
- Capacity of the CH_4 drainage system.

Factors Affecting CMM Quality

CMM is diluted with air that is drawn into broken strata by the gas extraction process, through inadequately sealed standpipes (a widespread problem in China's coal mines) and through leaking flanges and valves within the pipe network. Air is also admitted as new boreholes are connected into the network. Methane concentrations (purities) in drained gas can range from a few percent to in excess of 90 percent in exceptional circumstances.

Capture Efficiency

The performance of a methane drainage system is usually assessed in terms of methane capture efficiency which is defined as the ratio of drained gas to total gas in the airway and drainage system expressed as a percentage. The gas released from the coalface, from uncut coal left in situ and from coal cut by the coalface machine is not capturable (unless pre-drained for a very long period of time). The capture efficiency is, therefore, always less than 100 percent. Due to mining, geotechnical and engineering limitations, a gas drainage system would also be unlikely to capture all of the gas released from adjacent coal seams. Depending on mining conditions, geology, coal permeability, and method of methane drainage capture efficiencies can range from 30 percent to in excess of 90 percent. Capture performance is site specific and even on a particular longwall can vary over its length depending on geological and mining conditions.

Capturing More Gas

Better design, planning, and drainage system management will lead to higher gas captures, higher and more consistent gas purities. The benefits of capturing more gas are lower methane concentrations in the mine airways, higher coal production achievable and more gas for utilization. The most effective postdrainage methods of those used in China are drainage galleries in the roof and surface goaf boreholes. For example, goaf wells at Tiefa can produce 30,000 m^3/d of gas with a methane concentration of 80 percent. However, these methods only work well when the major sources of gas occur in the roof strata.

In mines where gas is drained ahead of mining from medium length boreholes drilled in developments and across projected longwall panels, ability to deliver gas is largely dependent on roadway development rates and the number of active developments areas. More gas can be drained by increasing the number of predrainage sites, provided they are not close enough to interact, and adding further gas extraction capacity.

However, where gas extraction pump capacity is increased without expanding the underground sources, the result is usually higher gas mixture flows and lower purity gas, often too low for utilization. This effect is exacerbated where gas is being drained from boreholes with inadequate standpipe seals – a common problem in Chinese coal mines and solutions are needed to ensure the concentration of the methane can be safely maintained at a usable level.

Utilization

A gas utilization scheme can be considered for any mine with a history of gas production, but the scale of the scheme will depend on current and future gas availability and, ultimately, on the market for gas sales. Reliability of gas supply can be increased by obtaining gas from more than one mine, or from different sources. The feasibility of CMM use depends on:

- The mining and geological setting;
- Gas drainage methods, gas quantities and qualities at the mine;
- Future gas availability based on the mining plan;
- Potential to improve drainage performance;
- The local market for medium heat value gas and electricity; energy prices;
- Possible utilization options;
- Availability of finance;
- Social, environmental and safety benefits; and
- Ownership of resources, land and permitting issues.

Some remote small- and medium-sized mines suffer interrupted power supplies due to capacity limitations on the local grid and others have lost coal production due to intermittent supply shortages. On-site power generation using CMM is therefore of interest to mining companies seeking to reduce their costs and ensure continuity of supply.

CBM/CMM projects at some coal mines offer ready market opportunities. A majority of coal districts are situated in the middle and east of China where industries are well established. Many coal districts themselves are small- or medium-sized cities that house the mine workers and support industry workers. Some large coal mines are near large commercially advanced cities, providing a potential market for CMM/CBM. Further, many mining districts have set up local CMM/CBM transportation systems and have substantial experience of gas distribution and utilization.

Annex IV

An Overview of Some Major CMM Extraction and Utilization Schemes

CMM schemes have been developed by many coal mining enterprises including Yangquan, Jincheng, Huaibei, Huainan, Kailuan, Hegang, and Tiefa. Brief reviews of a selection of major schemes are given below to illustrate current approaches to CMM use in China.

Jincheng Coal Mining Group (Shanxi province)

Jincheng Coal Mining Group is operating three nongassy coal mines and two gassy mines (Sihe and Chengzhuang). A CMM gas drainage and utilization is operational at Sihe mine and gas is also drained from the adjacent Chengzhuang mine. Gas contents range from 9 to 16 m^3/t with coal permeability reported as 0.05 to 3 mD. Gas is drained mainly in advance of mining from boreholes (70-80 percent). Over 1,000 in-seam boreholes have been drilled which are about 500 m in length.

The Sihe gas drainage system was started in May 2000 and currently drains more than 60 Mm^3 (planned to increase to 200 Mm^3). The former State Development and Planning Committee, now the NDRC, has approved a 120 MW_e power generation scheme at Sihe which will be developed with the assistance of an ADB loan. Mine gas will be supplied to the new 120 MW_e scheme generating power for supply to the local grid and any surplus gas fed to the existing 11 MW_e gas turbine utilization scheme. An agreement for electricity export is in place and a price of 0.25 yuan RBM/kWh agreed. Jincheng Coal Mining Group has identified other local sources of gas that may be required to ensure sufficient gas is available for power generation. These include the existing VCBM wells drilled at Panzhuang, any further wells drilled in the future and also gas from the adjacent Chengzhuang mine.

The existing CMM utilization scheme supplies gas to generate power from gas turbines (GTs) and steam turbines with a combined output of 11 MW_e. The first stage was completed in September 2000 and involved 2 x 2 MW_e GT plus 1 x 3 MW_e steam turbine, the second stage was completed in January 2002 and consisted of the other 2 x 2 MW_e GT. All the equipment is manufactured in China and the GTs have reportedly proven reliable since installation, operating about 11 months per year. The electrical efficiency is poor (low 20 percents) although the use of the heat for the steam turbine increases efficiency to about 28 percent. The current CMM scheme includes a 10,000 m^3 gas storage holder adjacent to the surface extraction station with a further 50,000 m^3 of storage capacity planned.

Fushun (Liaoning province)

Fushun Mining Group Co. Ltd. is a large State-owned coal enterprise in China. Currently, coal production in the Fushun mining area is about 6 Mtpa. Fushun is mainly producing blending coking coal and steam coal.

Fushun Mining Group Co. Ltd. is also rich in CBM resources that total around 8.9 Bm^3. Coal in this mining area is low in sulfur and ash content, and has well-developed fissures. Porosity of the coal is up to 10 percent. Fushun coal also has very good permeability which averages at 0.5- 38 md. Since coal seams in the Fushun mining area have high permeability, high gas content, good gas reservoir conditions and high methane content, conditions are favorable for the commercialization of CBM development and utilization. Since 1971, methane drainage from the Fushun mining area has been consistently high, generally above 100 Mm^3/a. In 2004, 110 Mm^3 was drained.

Coal mine methane extracted from Laohutai mine at Fushun is utilized in the city and also transported to nearby Shenyang. Both pre- and post-drainage methods are used although gas quality from predrainage can be poor due to inadequate borehole sealing. The annual gas extraction has remained over 100 Mm^3 since 1983. Figures for 2001 record gas extracted as 120 Mm^3. The CMM schemes include 188,000 m^3 of gas storage capacity.

Gas is supplied for residential use in Fushun and also via a 33 km pipeline to Shenyang city as part of a joint venture between Fushun CMA, Liaoning Coal Industry Management Bureau and Shenyang Coal Gas Co. The supply scheme to Shenyang has involved some 226 M yuan investment (EU sources state 58 M yuan). The gas supply capacity is 104 Mm^3/a but lesser quantities of gas are being transmitted due to purity problems. A further phase of development will involve drilling VCBM wells to provide high purity gas to enrich the mine gas and also increase the total volume of gas available.

Hegang (Helongjiang province)

Nanshan coal mine has an annual design capacity of 2.5 Mt/a. The mine is classified as an outburst prone mine. Both pre- and post-gas drainage methods are used and more than 1,800 extraction boreholes have been drilled. Gas contents of the principal mined coal seams; No.15 (average thickness 14 m) and No.18 (average thickness 16 m) are 12 m^3t^{-1} and 15 m^3t^{-1} respectively. Coal permeability is reported to be 0.8 to 1.6 mD.

Total gas extraction in 2001 was 1.3 Mm^3 with gas purity typically between 40 and 60 percent. Gas is supplied to 28,000 residential houses (started 1992) through some 12 km of main distribution pipework supplying 25,000 to 30,000 m^3 gas per day. The system includes a 10,000 m^3 and 20,000 m^3 gas storage holder adjacent to the mine plus a 10,000 m^3 and 5,000 m^3 gas storage holder located within the distribution system.

Key issues identified by the mine in developing CMM utilization are:

- Drilling technology to drill in-seam for predrainage;
- Lack of performance of current drilling equipment;
- Monitoring technology to manage gas drainage system; and
- Insufficient finance available to modernize and extend the scheme.

Songzao (Chongqing province)

The Songzao enterprise operates six mines with an annual production of 4 Mt. All the mines are classified as outburst prone with gas contents range from 17 to 21 m^3t^{-1}. Gas drainage has been practiced for many years and the group has considerable experience at the use of pre- and post-drainage methods.

Total gas extraction for 2002 was 93 Mm^3 (44 percent capture efficiency) with gas supplied to 222,000 residential users consuming just under 100,000 m^3 per day and other public bodies. Gas use is generally about 50 percent.

Gas storage capacity in the CMM scheme is 60,000 m^3. The Group is currently installing a 2 MW_e power generating facility (designed to operate at 6 MkWh).

Huaibei (Anhui province)

Huaibei coal mining area is located in the central part of east China and the northern part of Anhui province. With its size of 100 km from north to south and the same length from east to west, Huaibei coal mining area covers the total areas of Huaibei city, Fuyang city and Suzhou city. Huaibei coal mining area is about 9,600 km^2 of which the coal bearing area occupies 6,812 km^2. The entire Huaibei coal mining area includes Zhahe mining area, Suxian mining area, Linhuan mining area and Woyang mining area with a total proven coal reserve of 6.7 billion tons. Coal in Huaibei coal mining area is mainly high quality bituminous coal with low sulfur, low phosphorous and medium-low ash contents. Its calorific value is 5,000 = 8,000 kcal/kg. In addition to coal reserves, Huaibei coal mining area also has 150 Mt of natural coke, more than 300 billion m^3 of CBM and some other mineral resources.

Currently, the enterprise operates four mines. Gas contents range from 8 to 25 m^3t^{-1} with coal seam permeability reported to be 1.5 to 3.2 mD. Both pre- and post-gas drainage methods are used.

Total gas extraction in 2000 was 13 Mm^3 (21 percent capture efficiency). Gas is supplied to some 5,000 residential users and public welfare units and the scheme includes a 15,000 m^3 gas storage holder. There are plans to upgrade the current CMM scheme to 40 Mm^3 per annum with the option to increase this further to 70-80 Mm^3 per annum. A number of other gas uses have been identified including power generation and industrial process.

Yangquan (Shanxi province)

Yangquan Coal Group Co. Ltd. (YCG) is a large State-owned enterprise and the largest anthracite production base in China with a coal production capacity of 16 Mtpa, planned to increase to reach 22.5 Mt by 2015.

The coal resources are 14.1 Giga Ton (10^9 Tons) (Gt) and the CBM 687 billion m^3. The annual methane emission in Yangquan mining area is over 4 billion m^3. At present, there are eight methane drainage stations in operation and 120 Mm^3 methane is recovered annually.

The group operates 11 coal mines. Gas contents range from 7 to 22 m^3t^{-1} with the average 17 m^3t^{-1}. Gas drainage involves a combination of cross measures drainage, surface goaf boreholes and super adjacent headings. Gas is collected underground from 120 km of pipework. The feasibility of using CBM technology to pre-drain the gas by drilling from the surface has been examined.

Total gas extraction for 2001 was 151 Mm^3 but it is anticipated future annual gas capture will be around 130 Mm^3. Typical capture efficiency is about 40 percent. About one-third of the gas drained is used for residential use but this may be extended. Currently, some 134,000 residential users are supplied by a system which incorporates 210,000 m3 of gas storage facilities. Other end use options being considered are methanol synthesis and power generation.

Panjiang CMA (Guizhou province)

Panjiang Coal & Electric Power Group Co. (PCEPG) is the largest coal mining company in southern China. Coal resources in the Panjiang mining area are estimated at nearly 48 Gt and CBM at 124 billion m^3. Panjiang's six coal mines produce about 6 Mtpa. According to PCEPG's development plan, total annual coal output of the company will reach 21 Mtpa by 2010.

Seam gas contents range from 10-20 m^3/t. Total methane emissions from the six mines are around 200 Mm^3 per year. Expansion of coal production and the commissioning of new mines will further increase the availability of CMM.

CH_4 drainage could be increased to over 500 Mm^3/a if underground drainage and surface drainage were carried out simultaneously.

The group operates six mines with gas contents reported to be up to 20 m^3t^{-1}. Currently, gas control is achieved primarily by goaf drainage.

Total gas extraction for 2000 was 43 Mm^3 (about 25 percent capture efficiency). The gas capture capacity of existing equipment is 150 Mm^3 per annum, studies suggest that gas capture will increase to 500 Mm^3 per annum. Gas is supplied to 3,500 residential users and also used by the mines. Gas use in 2000 was 2 Mm^3 (<5 percent of the gas captured). There is a 20,000 m^3 gas storage facility. New projects being considered are an extension of residential use and for power generation.

Huainan Coal Mining Group (Anhui province)

The Huainan Mining Group Co. Ltd. is a large State-owned coal production base. Total planned coal production capacity is 37.6 Mtpa; coal production in 2004 was 30 Mt.

Total CBM resources belonging to the Huainan Mining Group Co., Ltd. are estimated at 593 Bm^3. Strong potential for the development of these resources exists, and there is a broad market for utilization of the recovered gas. The CBM field covers about 2,242 km^2, average CBM resource density reaches 264.4 Mm^3/km^2.

Current emission of coal mine gas is 600 m^3/min, and annual methane emissions are 311 Mm^3, ranking Huainan third highest methane emitter among Chinese mines. In 2004, CMM recovery from the Huainan mining area was nearly 150 Mm^3.

Huainan operates nine mines. Gas contents are reported to range from 10 to 20 m^3t^{-1}. All the mines are classified as gassy with total emissions 300-350 Mm^3 per year. Gas recovery in 2002 was 108 Mm^3 (30 percent capture efficiency) and it is anticipated this will be rising from 130 Mm^3 in 2003 to 300 Mm^3 in 2010 of which 100 Mm^3 will be used.

The Huainan CMM gas utilization project has been approved at State level. The total cost of the project is 240 million yuan. Gas use options are residential use, power generation and use in boilers to replace coal burning. A total of 70 Mm^3 of gas will be used (about 50 percent utilization) from six of the mines.

Both pre- and post-gas drainage methods are used. Predrainage is undertaken up to five years in advance of mining allowing gas contents to be reduced by 26 percent before mining takes place. Typically, 10-20 percent of gas is recovered using predrainage methods and 80-90 percent using postdrainage methods.

Pingdingshan

Pingdingshan Coal Group Co. Ltd.(PCG) produces 19 Mtpa of coal. According to the development plan of the company, annual coal production will be maintained at around 23.50 Mt during the next 10 years. The proven coal reserves are around 7.6 billion tons while the recoverable CBM resources are estimated at 65.2 billion m^3. All 14 of the active coal mines are gassy with gas contents in the major recoverable coal seams of 6-15 m^3/t.

In 2000, the annual total CH_4 emissions in this mining area were recorded at over 200 Mm^3. Along with the increase of mining depth and increasing coal production capacity, methane emission also has been increasing over the past years. So far, nine out of the total of 14 coal mines of PCG have been equipped with underground gas drainage facilities. Three of them are using surface pump stations. The year 2000 witnessed the total extraction of 25.88 Mm^3. With more pump stations completed and commissioned, CMM drainage would experience further marked growth.

Annex V

General Principles of CBM Production-sharing Contracts

The general principles of the CBM PSCs are:

- CBM resources in the contracted areas for foreign cooperation shall be owned by the People's Republic of China;
- The investment interest of the foreign party shall be protected by Chinese laws, and the foreign party shall be subject to Chinese laws;
- The foreign party should provide exploration investment and undertake the exploration risk. After a commercial CBM field is found, the two parties shall input certain investments and jointly carry out development and production;
- The foreign party has the right to withdraw during exploration from the CBM contract after it has completed the minimum work commitment;
- During the exploration period, the contract areas (except the development area and production area) should be relinquished in increments;
- Under the management of the Joint Management Committee with the Chinese party acting as the Chairman, a Joint Operating Agreement is formulated which controls the operations; the Chinese party may elect to have zero equity interest or it could be around 50 percent. The foreign party recovers the exploration and development investment costs as priority;
- All the materials and data obtained from the operation in the contracted area shall be owned by the Chinese party;
- After the development investment is recovered by the foreign party or the contract is terminated, the assets in the contract area shall be owned by the Chinese party;
- The contract effectiveness, right transfer, and overall development plan for the CBM field shall be approved by the Chinese government department concerned;
- The foreign party shall give priority to employing Chinese personnel, Chinese contractors, and services;
- The foreign party shall provide training for and technology transfer to Chinese personnel;
- The foreign party can receive a return on investment and expenses from the CBM production, and obtain profit in accordance with the contract stipulations;
- The foreign party shall pay various taxes and royalties according to the Chinese laws; and
- The Chinese party shall help operators solve operational CBM problems.

Financial Sharing Model of the Standard Contract

- The foreign company undertakes the exploration risk solely, namely the foreign company undertakes all the exploration investment, and the foreign company should agree to the minimum compulsory exploration work and the minimum exploration expenditure. The amount of the compulsory work is an important condition of bidding competition among foreign companies. If no commercial CBM field is found, the Chinese party does not have the obligation to compensate the exploration expenditure of the foreign company;

- After a commercial CBM field is found, the Chinese party will participate in the development with an investment share not greater than 51 percent; the investment share of the foreign party is 49 percent. If the investment share of the Chinese party is less than 51 percent, the foreign party can increase its investment share accordingly, but the investment share of the Chinese party shall be not less than 30 percent;

- CBM recovered (sales revenue) shall be allocated in proper order. That is to say, a certain proportion of the total CBM production is taken to pay the value-added tax at a rate of 5 percent to the Chinese Government, pay the royalty according to the annual CBM production, and then reimburse the operation costs of the two parties, in the end reimburse the exploration and development expenditure. If the total investment and the interest of the two parties cannot be returned fully when the contract is terminated, it can be treated as a loss of the two parties, and will not be returned; and

- The surplus gas, namely the annual total production minus that paid for value-added tax, royalty, operating costs, and norm of investment return, is shared by the two parties. The surplus gas can be divided into two parts: "reserved gas of the Chinese party" and "Sharing gas" allocated to the two parties according to their commitment to the development investment. The relative proportion of the two parts is also an important condition in bidding competition among foreign petroleum companies, and is determined by contract negotiation.

Further Details of the Standard Contract Finance Sharing Model

- VAT shall be 5 percent in kind for CBM cooperative projects. VAT shall be 13 percent for CBM projects self-financed by Chinese at the beginning with 8 percent returned later, resulting in an actual VAT of 5 percent;

- Royalties shall be imposed and calculated on the basis of gross CBM production in each calendar year for each CBM field (Tables A5.1 and A5.2);

- Seventy percent of the annual gross production of CBM shall be deemed as "cost recovery CBM." The sequence of its payment or recovery is as follows: when the price is

Table A5.1: Royalty Rates for CBM Cooperation Projects in Three Provinces and Regions of Qinghai, Xizang, Xinjiang and Shallow Sea Region

Annual Gross CBM Production (x $10^8 m^3$)	Rates (%)
Equal to or less than 20	0
20 to 35	1
35 to 50	2
Over 50	3

Table A5.2: Royalty Rates for CBM Cooperation Projects in Other Provinces, Autonomous Regions and Cities

Annual Gross CBM Production (x $10^8 m^3$)	Rates (%)
Equal to or Less than 10	0
10 to 25	1
25 to 50	2
Over 50	3

determined, payment for operating costs actually incurred by both parties shall be recovered first;

- The remainder shall be deemed as "investment recovery CBM." Exploration costs shall be recovered first, then the development costs and interest;
- After the recovery of the investment, the remainder shall be deemed as "remainder CBM" to be shared by both parties; and

- The remainder of the CBM shall be divided into two parts: one part as "share CBM," the other part as "allocable remainder CBM." The parties in proportion to their actual respective participating interests adjusted by a factor, X, shall allocate the "allocable remainder CBM." The method for calculating X is the same as that of calculating royalty, but the rate differs. Factor X is determined by negotiations.

For example: Suppose the remaining CBM is 1×10^8 m^3, X is 90 percent, participating interest of the Chinese party is 51 percent, the participating interest of the foreign party is 49 percent, then:

Remaining CBM by the State = (100%-90%) 1 = 0.1 (x 10^8 m^3)

Allocated CBM by Chinese Party = 51% × (100%-90%) = 0.459 (× 10^8 m^3)

Allocated CBM by Foreign Party = 49% × (100%-90%) = 0.441 (× 10^8 m^3)

Standard Contract Terms

- Contract Area: surface area with geographic coordinates for the cooperative exploitation of CBM resources designated by the host government;
- Contract Term: exploration, development, and production phases;
- Minimum Exploration Work Commitment: minimum exploration work or other work commitments that shall be performed or financed by the foreign company;
- Economic Benefit: measure of obtaining benefits through cooperation by the State company and foreign company;
- Investment Recovery: generally a certain percentage to be recovered in the annual gross CBM production;
- CBM Price, including quality, quantity. The price is in term of FOB;
- Taxation;
- Preference for the employment of Chinese personnel, goods, and services;
- Training of Chinese personnel and transfer of technology;
- Ownership of assets and data;
- Solutions to the disputes; and
- Other content.

Annex VI

Preferential Finance and Tax Policies for CMM/CBM

Adapted from China Coalbed Methane Clearinghouse, Investment Guide for China CMM/CBM, April 2004.

Policies Encouraging CMM/CBM Development in China

Since the 90s, the Chinese Government has provided the CBM/CMM industry with a variety of economic incentives. To guide and promote the national economy, China's Government enacted three important documents:

- List of Comprehensive Utilization of Resources;
- Catalog of the Industries, Products and Technologies Currently Encouraged by the State for Development; and
- Guidance Catalog of Industries for Foreign Investment.

In addition, to promote development in the poorer western regions, the government introduced a suite of preferential policies which complement the above.

List of Comprehensive Utilization of Resources

In 1996, the State Economic and Trade Commission, the Ministry of Finance, and the State Administration of Taxation officially placed the items "coal mine gas recovered and its processed products" and "utilization of CBM for power and heat generation" in the revised List of Comprehensive Utilization of Resources. All production and construction projects included in the List can enjoy the comprehensive utilization preferential policies stipulated in five documents issued by the State Council, the Ministry of Finance, and the State Administration of Taxation.

Besides the above advantages, comprehensive utilization projects with CBM development also enjoy the advantages of reduced income tax according to the No. [1996] 36 Document issued by the State Council. The document states: "The enterprises using the wastes in 'The Catalog of Comprehensive Utilization of Resources' as raw materials are duty-free or can reduce the amount of income tax to be paid. Projects that use wastes generated during the production of their own enterprises are duty-free for five years from the time the projects begins. Those which use the wastes of other enterprises can be duty-free for one year according to the approval of the director of tax authorities."

The preferred use of CMM is to generate power. The projects that generate electricity fueled by CMM and included in the List enjoy the following advantages:

- For an enterprise that uses CMM to generate electricity and heat, if its installed capacity exceeds 500 kW, and it is eligible for connecting to power grid, the power sector should admit its access, and sign a contract. Thus, the fee for a small thermal power plant to enter connect to the grid will be exempted and the electricity will be given priority for sale within the rated electricity amount permitted to enter into the grid; and

- The comprehensive utilization power plant whose installed capacity is at or below 1.2 MW does not take part in the electric network peak adjustment. The comprehensive utilization power plant whose installed capacity is over 1.2 MW plan certain peaking capacity and permit peak full output, but the power generation load cannot be less than 85 percent of the rated power of the generating equipment while in a valley.

Catalog of the Industries, Products and Technologies Currently Encouraged by the State for Development

In 1997, the State Planning Commission published the Catalog of the Industries, Products and Technologies Currently Encouraged by the State for Development, in which, "CBM exploration, development and utilization" and "Development and utilization of low heating value fuels and associated resources in coal mines" were formally listed. The investors enjoy exemption of import tariffs and import link VATs if they invest in any projects, such as CMM/CBM projects, as they are included in the Catalog.

Guidance Catalog of Industries for Foreign Investment

In 2002, the State Planning Commission, the State Economic and Trade Commission, and the Ministry of Foreign Trade and Economic Cooperation jointly issued the Guidance Catalog of Industries for Foreign Investment, in which two types of investment projects, "CBM exploration and development" and "Development and utilization of low heating value fuels and coal mine associated resources" were included.

According to the Guidance Catalog, foreign investment projects are put into four categories: encouraged, allowed, restricted, and forbidden terms. The foreign investment projects classified as encouraged can enjoy preferential treatment in accordance with the stipulations in the relevant laws and administrative regulations. CMM/CBM projects are listed in as encouraged in the Guidance Catalog.

Preferential Policies for Western China Development

At the beginning of 2000, the Chinese Government began to enact the strategy to develop its western resource reserves and had a clear mandate. The State Council established a working group that held a conference on developing western China. The working group developed a plan for constructing the infrastructure and environment-friendly policies required for western China's resource development.

In order to advance the development strategy, the central and local governments established a series of preferential policies and rules. Starting from January 1, 2000, the internal revenue service began to provide tax incentives to foreign investment enterprises in midwest China including Shaanxi, Gansu and Guizhou CMM areas with a reduced tax rate of 15 percent for three years. On June 16, 2000, the China Government established and enacted "The Contents of Prior Industry Invested by Foreign Businesses in the Midwest." The policies are more attractive to foreign capital and set up the conditions for foreign investment enterprises. The projects that adhere to the guidelines presented in the "Contents" document enjoy the policies in the "Provisional Rule of Instructing Foreign Investment Aspects" and "Notice for Further Encouraging Foreign Investment Opinion Transmitting by the State Council General Office from the Ministry of Foreign Trade" (No. [1999] 73).

Taxation Policies for CBM Exploration and Development Projects

In order to encourage foreign investors to invest in CBM exploration and development in China, the Chinese government issued the "Notice on

Taxation Policies Concerning Foreign Petroleum Companies' Participation in Coalbed Methane Development in China" by the Ministry of Finance and the State Administration of Taxation. In the document, applicable taxation policies are stipulated as follows:

- Operation income and other incomes obtained by the enterprises that develop onshore CBM resources in China shall be taxed in accordance with the stipulates in the "Income Tax Law of the People's Republic of China for Enterprises with Foreign Investment and Foreign Enterprises" and Rules for the Implementation;
- The stipulations in the "Rules for Implementation of the Income Tax Law of the People's Republic of China for Enterprises with Foreign Investment and Foreign Enterprises" regarding "enterprises engaged in petroleum production" are also applicable to enterprises engaged in development of onshore CBM resources;
- Unless otherwise specified, the stipulations formulated by the Ministry of Finance, the State Administration of Taxation, and the Offshore Petroleum Taxation Bureau concerning income tax for the enterprises engaged in cooperative development of oil resources are also applicable to the enterprises engaged in the development of onshore CBM resources;
- For the revenues obtained by developing onshore CBM, the VAT and royalty of developing onshore CBM shall be paid in accordance with the "Notice of the State Administration of Taxation on Value-added Tax of Petroleum Production in Foreign Cooperation Projects" (issued by the State Administration of Taxation in 1994) and the "Provisional Regulations Governing Royalty Payment for Onshore Petroleum Development in Foreign Cooperation Projects" (issued by the Ministry of Finance in 1990). Urban real estate tax is about 1.2 percent and vehicle and ship license tax varies according to the type, these taxes should be paid when the purchase happens.

Enterprises engaged in onshore CBM development shall pay urban real estate tax according to the "Provisional Regulations Governing Urban Real Estate Tax"; pay vehicle and ship license tax according to the "Provisional Regulations Governing Vehicle and Ship License Tax"; and pay stamp duty according to the "Provisional Regulations Governing Stamp Duty of the People's Republic of China."

In accordance with the above regulations, foreign investors shall pay the taxes and enjoy the preferential treatment as described below.

Enterprises Income Tax

According to Item 5 of "Income Tax Laws of the People's Republic of China for Enterprises with Foreign Investment and Foreign Enterprises" (hereafter referred to as the Tax Law) enforced on April 9, 1991, "The income tax on the foreign investment enterprises and the income tax on earnings the foreign enterprises received from the production and operation of institutions set up in China shall be calculated in accordance with the amount of income that shall be paid, whereas the tax is 30 percent, and the local income tax shall be calculated in accordance with the amount of income that should be paid, whereas the tax is 3 percent."

According to Article 8, "To the productive foreign-investment enterprises whose operation period is more than 10 year, the business income tax is free in the first and second year, and the business tax is reduced by half from the third year through the fifth years. But to those enterprises which engaged in such development projects as petroleum, natural gas, rare metals and noble metals will be regulated by the State Council. If the actual operation period of the foreign investment enterprise is less than 10 years, the enterprises should pay the business income tax that was originally tax free and/or reduced."

According to Article 9, "To the industries and projects which we encourage the foreign businessman to invest, the government of the province, municipality and the municipality directly under the central government can decide to exempt and reduce the local income tax according to the practical situation."

According to Article 10, "The foreign investors of the foreign investment enterprises can directly put the profits obtained from the enterprise into the investment for the enterprise, increasing the registered capital, or they can launch other foreign investment enterprises using these profit as capital. If the operation period is not less than five years, 40 percent of the income taxes of the reinvestment that were paid will be returned, following the application of the investor and the approval of the tax authorities. For those who have the special preferential policy from the State Council, will transact according to the regulations of the State Council; for those who leave less than five years after the investment, they should return the taxes that were handed back."

According to Article 11, "If the production operation institutions and sites set up by foreign investment enterprises and foreign enterprises in China have losses in a year, they can recoup the losses from the earnings of the next tax year; if the earnings of the next tax year are not enough, they can continue to make up year by year, but not to exceed five years."

According to Article 29 in the Tax Law, the State Council issued "Rules for Implementation of the Income Tax Laws of the People's Republic of China for Enterprises with Foreign Investment and Foreign Enterprises" (hereafter Rules) on June 30, 1991.

According to Article 32, "The development-stage investment of the enterprises engaged in developing oil resources should look at the oil (gas) field as a unit, add up entirely and payout as capital payout, then calculate the depreciation from the next month of when the oil (gas) field starts commercial production."

According to Article 36, "For the enterprises engaged in developing oil resources, the fixed assets formed by the investment during the development stage and the period following can be synthetically calculated as depreciation, without salvage value, and the depreciation time limit should not be less than six years." If the economic benefit of the oil (gas) field is poor or its productive life is less than six years, then the enterprise can apply to calculate the depreciation in accordance with the production method.

According to Article 48, "The rational exploration fee of the enterprises engaged in developing oil resources, can amortize the income by stages among the oil (gas) fields that have started commercial production; and the amortization time limit should not be less than one year. In the case where a contract is terminated because no commercial oil or gas field is found in the contract area of a foreign company, if the company does not continue to hold contract for exploitation of oil or gas resources and does not keep its business organization or office in China. Reasonable exploration expenses of the company in the terminated area, after reviewed and confirmed by the tax authorities with certificate, could be amortized in the production revenue from its new contracted area, provided that the new contract is signed within ten years after the contract is terminated."

Article 2 in "The Notice of Tax Issues on Transfer and Receiving Petroleum Contract Between Foreign Companies" states that the receiving payout to the foreign company receiving petroleum contract equity can be looked upon as the exploration fee and the development investment spending, and will be amortized and depreciated in accordance with the Rules.

Value Added Tax, Resource Tax and Royalty

As is the case for regulations for developing petroleum and natural gas reserves, the value-added tax and resource tax for CBM development projects invested by international partnerships should be managed in accordance with the following regulations:

Item 1 in "The Decision of the Interim Regulations Concerning the Value Added Tax, Consumption Tax and Sales Tax Applied to Foreign investment Enterprise and Foreign Enterprise" issued on December 29, 1993, specifies that, "The Value Added Tax is collected in accordance with the practicality when developing offshore oil and natural gas by Sino-foreign cooperation, the tax rate and collection method are regulated by the State Council."

At the same time, the State Council issued "The Notice of the Interim Regulations Concerning the Value Added Tax, Consumption Tax and Sales Tax Applied to Foreign investment Enterprise and Foreign Enterprise" (February 22, 1994).

Item 3 concerning the tax for developing oil resources by Sino-foreign cooperation, requires that the Value Added Tax of crude oil and natural gas is collected in product, a tax rate of 5 percent, a mining royalty in accordance with standing regulations, and deferred resource tax. There is no tax rebate for export of raw oil and natural gas.

The royalty is collected in accordance with "The Notice of Amended 'The Interim Provision of the Mining Royalty Paid when Developing the Oil Resources Onshore by Sino-foreign Cooperation' " in 1995.

Tariffs and Other Taxes

In order to further increase the utilization of foreign investment, introduce foreign advanced technology and equipment, as well as to promote industry structural readjustment and technological progress, the State Council decided that any foreign investment project belonging to the Encouraged and Restricted B of the Guidance Catalog of Industries for Foreign Investment can enjoy exemption of import tariffs and to import link value-added tax, except those listed in the imported equipment category which are not allowed to enjoy exemption. The specific measures are executed in accordance with No.1602 Document issued by the State Administration of Customs in 1997.

In order to encourage foreign investment in different regions, the local governments at various levels have worked out a series of preferential policies regarding auxiliary taxes including local income tax, vehicle and ship license tax, and urban real estate tax, and others.

The "Mineral Resources Law of the People's Republic of China" stipulates that the acquisition of exploration and development rights will be executed in China. The user charge for the exploration right is 100 yuan/km/yr within first three years. The user charge for the development right is 1,000 yuan/km/yr. For those that can be exempted, the user charge may be reduced, exempted, or allowed to be paid after being approved.

Annex VII

Internationally Financed CBM and CMM Projects

In the 90s, UNDP/GEF funded CBM and CMM extraction technology transfer and demonstration projects involving vertical CBM wells, underground long hole drilling and surface goaf boreholes. Technical assistance, training and equipment was supplied to China, mainly from the United States, through the following United Nations Development Programme (UNDP) projects:

- CPR92G31:Development of CBM resources in China (from April 1992);
- CPR92G32: China CBM resource development (from June 1992, including underground long hole drilling and surface goaf wells at Tiefa);
- CPR91214: Exploration for deep CBM (from Feb 1993 for 3.5 years); and
- CPR91S14: Exploration for deep CBM.

The five-year UNDP-GEF technical assistance project CPR92G31 involved four subprojects at: Tiefa, Liaoning (underground long hole drilling and surface goaf wells), Kailuan, Hebei (drilling of three surface wells, maximum production 2,000 m^3/d from one well, others poor), Shaanxi (exploration and resource assessment), Songzao, Sichuan (underground long hole drilling in which limited success was achieved in very difficult geological conditions). Some problems were encountered due to lack of understanding of Chinese conditions by consultants and use of inappropriate equipment. Notable successes were the demonstration of effective of surface goaf borehole drainage at Tiefa which has been replicated subsequently, capacity-building and the subsequent development of CCRI Xi'an as a major CBM service provider in China and raising the awareness of government of the potential of CMM and CBM as energy resources that China should and could develop. Thus, there was a positive policy impact. UNDP-GEF contributed US$10 million and the China Government 40 million yuan.

Initiated in August 1993 and completed in December 1996, the exploration for deep CBM project was carried out in three phases: geological evaluation and selection of target areas, gas production experiments from a group of pilot wells and assessment of development potential and economics. A pilot site at Liulin in the Hedong coalfield of Shanxi province was selected following a geological appraisal of Liulin, Chenge, Taidong, Huainan, Pingdingshan, Jiaozuo, Binchang, and Qinshui coalfield areas. The anthracite areas of the Jiaozuo, Qinshui, and Taidong coalfields were initially (and in the case of South Qinshui, mistakenly) thought to be of high risk and sites were initially selected which had coals with ranks similar to those of the Black Warrior and San Juan basins in the United States. The project was a technical success, the seven gas wells at Liulin having produced from 1,000 m^3/day to over 7,000 m^3/day. Although pilot production of VCBM was successfully demonstrated for the first time in China at Liulin, the relatively small prospect still has not been developed into a commercial project by subsequent foreign invested joint venture license holders.

The Liulin project, was undertaken jointly by the China Government (represented by CICETE) and the United Nations (UNDP) at a total cost of US$1.7 million (UNDP provided a grant of US$1.3 million and the Government of China contributed US$0.4 million). The North China Bureau of Petroleum (NCBP), under the auspices of the Ministry of Geology and Mineral Resources, acquired training and new skills in geology, drilling, well completion, laboratory techniques, well testing, fracturing and design, production reservoir evaluation and financial appraisal methods. Equipment and software were also purchased under the project. The technology transferred to NCBP by specialists from the United States provided the organization with a capability to undertake all aspects of virgin CBM exploration and development. NCBP subsequently signed exploration contracts with Enron (U.S.), Amoco (U.S.) and Lowell (Australia) but none of these projects led to commercial production. Nevertheless, domestic companies gained practical knowledge and expanded their capabilities.

These aid projects were aimed principally at achieving technology transfer and for some years Chinese VCBM activities focused almost wholly on spot drilling at locations with no thought as to long-term development needs and potential commercial feasibility issues.

Attempts were made to introduce advanced underground drilling equipment from Australia and the United States to enhance methane drainage but it has either been unsuited to geological conditions in China or too costly to maintain. Both the United States and Australian contractors experienced difficulties in trying to drill a long in-seam borehole at Songzao. Long hole in-seam drilling using imported drilling equipment also failed at Fushun, Pingdingshan, and Huainan due to problems with soft coal and high stresses. The expected benefits of introducing new CBM technologies have therefore not always been realized. There is a clear need to examine the drilling systems and technology in use in China and to better match gas control solutions to the geological and mining conditions .

Japan Coal Energy Center (JCAO) carried out a comprehensive CMM recovery and utilization project at Tiefa which was completed in October 2002. The project included demonstration of a state-of the-art gas control safety management system which is soon to be replicated in another mine. This scheme, involving major investment in underground drilling equipment, gas collection, gas storage and gas transmission was assisted by a contribution of US$7.4 million from the Japanese New Industrial and Development Agency.

The U.S. Environmental Protection Agency (USEPA)-sponsored research in 1999 to identify and develop prospectuses for the most promising coal mining areas for CBM/CMM development. The work was undertaken by the China Coalbed Methane Clearinghouse which was established by the USEPA at CCII more than eight years ago to promote CMM/CBM development. Jincheng, Huainan, Fushun, Tiefa, Panjiang, and Pingdingshan mining areas were identified as good prospects for CMM/CBM development. Further details of these key areas are provided in Annex IV. Over the last several years, CBMC, sponsored by USEPA, has been working in concert with Chinese coal mining companies to introduce interested investors and developers to CMM project opportunities in the main gassy coalfield area of China. CBMC has published and released seven brochures outlining potential projects but the aim of stimulating external investment has not been fulfilled as the information is too general and the project analysis superficial. However, dissemination of the documents has proved useful in highlighting key coal mines for CDM project development. The profile of CCII as a prime source of information, contacts and services in respect of CBM/CMM has, however, been raised to an international level and it is in these respects that a valuable contribution to CMM development in China has been achieved.

Since early 2002, CBMC has turned its attention toward a broader goal of promoting and supporting commercialization of CMM projects in China. The strategy undertaken by CBMC includes a variety of activities designed to disseminate information to investors and organizations worldwide, and to strengthen the capabilities of CMM and CBM professionals within China. International workshops organized by CBMC have been particularly effective in encouraging the sharing of international and domestic experience and the introduction of foreign technology suppliers, practicing engineers, innovators, research organizations, academics and trade officials to CMM and CBM potential in China. Failure by China to tackle the barriers and develop a market within which open and fair competition can drive change has resulted in the stagnation of most initiatives.

The U.K. DTI has co-funded a series of technology transfer projects involving CBM, CMM, AMM, and the development of a CDM methodology concept for CMM and the Foreign and Commonwealth Office (FCO) global opportunities fund is supporting a capacity-building project to promote the application of CDM for accelerating reductions of gas emissions from coal mines in China. These projects are aimed at introducing U.K. technology providers to China and providing a shop window for the U.K. expertise. Although modest in scale, the projects have enabled a wide spectrum of the U.K. consultants, service providers and manufacturers to establish sustainable links with counterpart Chinese organizations and enterprises, and there is a strong U.K. involvement in developing and financing CDM for CMM utilization projects in China.

The ADB has carried out various technical studies and approved loans of US$233 million for projects totaling US$372 million for a 120 MW_e CMM power plant at Sihe mine, a CMM pipeline collection and distribution in the area of Jincheng municipality and a CBM/CMM development project at Fuxin in Liaoning province.[6]

Demonstration projects have not always been widely replicated even when technically hailed as a success. Reasons include equipment unsuited to Chinese conditions, high cost of spares, equipment complexity, lack of follow-up support and insufficient training. The early CBM demonstration projects did not lead to commercial developments as site selection and project design did not take account of economic feasibility. Chinese exploration and development companies also initially failed to recognize the importance of market development. Any future CBM/CMM demonstration projects should not be purely technology focused but should be combined with policy, market and strategic development aims.

[6] *The financing includes for improvements to district heating and gas distribution systems in various cities in Liaoning.*

References

CCII (2004). *China Coalbed Methane Clearinghouse, Investment Guide for China CMM/CBM*, April 2004.

China Statistical Yearbook: http:/ www.stats.gov.co/english/statisticsdata/ yearlydata/

Creedy D. P., Garner K. (2004). Methane control technology for improved gas use in coal mines in China. Report No. COAL R257 DTI/Pub URN 04/1019, February 2004.

Liu, Jiang (2005): The Challenge of Climate Change and China's Response Strategy, http:// www.ccchina.gov.cn/english/source/ba/ ba2005032401.htm.

Liu Liguang. Draft thesis. Private communication, February 2006.

Mingxun Jie (2005). Present situation and prospects of CBM industry in China. The 1st China International Conference Proceedings on Coal Mine Gas Control and Utilization. October 26-27, Beijing, pp. 275-277.

MRI et al. (2004). Toward a Sustainable Coal Sector in China, Joint UNDP/The World Bank Energy Sector Management Assistance Program (ESMAP), June 2004.

NCCCC (2004): Initial National Communication on Climate Change of China, October 2004.

Shanxi (2005). The report of comprehensive utilization and development of coalbed methane in Shanxi. Shanxi provincial government. 22 September 2005.

Su Shulin (2004). The Prospect for The Development of China's Natural Gas Industry, China International Petroleum & Petrochemical Industry Summit, September 20, 2004.

World Coal Institute (2005). Quarterly newsletter, Vol. 54, July 2005.

Wu Yin (2005). Prospect for Coalmine Gas Control in China, The 1st China International Conference Proceedings on Coal Mine Gas Control and Utilization, 26-27 October, Beijing.

Yu Zhufeng (undated). *China's priorities and opportunities in Reducing Greenhouse Gas Emissions*, CCERC, China.

Additional source material

Clean Development Mechanism. China Meteorological Press. 2003.

Fan Jingkun. CBM Resources and Drainage Technologies in Huaibei Coalfield. *China Coalbed Methane*. Vol. 1 No. 2, Nov. 2004: pp. 28-31.

He Tiancai. Practice and Propects of CMM Recovery in Sihe Mine of Jincheng. *China Coalbed Methane*. Vol. 2 No. 3, Jul. 2005: pp.16-18.

Investment Guide for CBM/CMM prepared by China Coal Bed Methane Clearinghouse, China Coal Information Institute for USEPA, April 2004.

Investment Opportunities in Coal Mine Methane Projects in Huaibei Mining Area. USEPA & China Coalbed Methane Clearinghouse, 2001.

Investment Opportunities in Coal Mine Methane Projects in Jiaozuo Mining Area. USEPA & China Coalbed Methane Clearinghouse, 2001.

Investment Opportunities in Coal Mine Methane Projects in Panjiang Mining Area. USEPA & China Coalbed Methane Clearinghouse, 2001.

Jie Mingxun. CUCBM's Strategic Ideas for Making Near-future Program of CBM Exploration and Development. *China Coalbed Methane*, July 2004. Vol. 1 No. 1: pp. 7-9.

Jie Mingxun. Present Situation and Prospects of CBM Industry in China. The 1st China International Conference Proceedings on Coal Mine Gas Control & Utilization, 2005. pp. 275-277.

Jin Xueyu. Current Comprehensive Utilization and Progress of Coalbed Methane in Huainan Coal Ming Area. *China Coalbed Methane*. Vol. 1 No. 2, Nov. 2004: pp. 23-27.

Karl Schultz. Impact of CDM on Chinese Coal Mine Methane Industry. *China Coalbed Methane*. Vol. 2 No. 1, Jan. 2004: pp. 8-13.

Li Guishan. CBM Development and Utilization and It's Near- Term Targets in Jincheng Anthracite Mining Group. *China Coalbed Methane*. Vol. 2 No. 2, Apr. 2004: pp. 17-19.

Sui Yulin. Planning and Development of Fushun Coalmine Methane. *China Coalbed Methane*.Vol. 1 No. 1, July 2004, pp. 43-44.

Sun Maoyuan. Current Status and Prospects of CBM Industry in China. *China Coalbed Methane*. Vol. 2 No. 3, Jul. 2005: pp. 3-5.

Sun Maoyuan, etal. *Study Into The Policy of China's Coalbed Methane Industry*. China Coal Industry Publishing House. 2003.

Sun Maoyuan, et al. Development and Utilization of Coalbed Methane in China and Cooperation with abroad. China Coal Industry Publishing House. 1999.

Wang Wangui, Cao Ligang. The Prospect Analysis of the Development and Utilization of Coalbed Methane in Liaoning. *China Coalbed Methane*. Vol. 1 No. 2, Nov. 2004: pp. 32-34.

Wang Yan. Promotion of CMM Utilization in Huainan Coal Mining Area by Clean Development Mechanism. *China Coalbed Methane*. Vol. 2 No. 3, Jul. 2005: pp. 42- 46.

Yuanliang, et al. Latest Progress of GAS Drainage Technology and Reduced Emission as well as Utilization Scheme in Huainan Mine area. *China Coalbed Methane*. Vol. 1 No. 1, July 2004: pp. 39-42.

Zhang Guoliang, Sun Maoyuan. Study on Policies of Cooperation with Overseas Partners in China's Coalbed Methane Industry. *China Coalbed Methane*. Vol. 1 No. 2, Nov. 2004: pp. 3-6.

Zhang Jianbo, Wang Hongyan, et al. Progress of CBM Exploration Research. *China Coalbed Methane*. July 2004. Vol. 1 No. 1: pp. 13-16.

International comparative experiences

Andrews-Speed P. (2003). Foreign Investment in Exploration and Production in China. Global Outlook.Business briefing: Exploration and Production: *The Oil & Gas Review*, Vol. 2, 2003.

CEC (1996). California Energy Commission (CEC) Energy Technology Status Report 1996. Sacramento.

Creedy, D.P. (1993). Methane Emissions from Coal Related Sources in Britain: Development of a Methodology. Chemosphere, Vol. 26, Nos. 1-4, pp. 419-439, 1993.

Creedy D P, Garner K, Holloway S, T X Ren (2001) A review of the worldwide status of Coal Bed Methane extraction and utilisation. Report No COAL R210, DTI/Pub URN 01/1040, July 2001.

DTI (2004a). Methane control technology for improved gas use in coal mines in China. Report No. COAL R257 DTI/Pub URN 04/1019, February 2004.

DTI (2004b) Coal Mine Methane – Review of the Mechanisms for Control of Emissions. IMC (with Ecosecurities and Ernst & Young), Feb04, Report R256, DTI URN 04/865.

David G. Streets, Kejun Jiang, Xiulian Hu, Jonathan E. Sinton, Xiao-Quan Zhang, Deying Xu, Mark Z. Jacobson, James E. Hansen (2001). Recent Reductions in China's. Greenhouse Gas Emissions, www.sciencemag.org., *SCIENCE* Vol. 294, 30 November 2001, pp. 1835-1837.

EEA (2005): Greenhouse Gas Emission Trends and Projections, European Environmental Agency.

EIA (2005): International Energy Outlook 2005, Energy Information Administration, U.S. Department of Energy, 2005.

Francisco de la Chesnaye (2001). *Modeling non-CO_2 Greenhouse Gas Emissions and Mitigation & the Importance of a Multi-gas Abatement Strategy*, 4th Sino-Korean-U.S. Economic & Environmental Modeling Workshop, Beijing, China - May 2001.

http://www.methanetomarkets.org/coalmines/coalmines-bkgrd.htm.

IEA (2005): IEA Energy Statistics. http://www.iea.org/Textbase/stats/index.asp.

IEA (2005): World Energy Outlook 2004.

Irving W., Tailakov O. (undated). *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, CH4 emissions: Coal Mining and Handling.

Mutmansky J. M. (1999) White Paper: Guidebook on Coalbed Methane Drainage for Underground Coal Mines, April 1999 pp. 51.

On-Shore Oil, Gas and Coalbed Methane Development, Office of the UK Deputy Prime Minister, draft Minerals Planning guidance Note, 1999.

Review of the Mechanisms for Control of Emissions. Report No. COAL R256 DTI/Pub URN 04/865, February 2004.

Safety and Health In Mines Research Advisory Board (2003). Review of Explosion Protection of U.K. Coal Mine Methane Extraction Systems, Annual Review 2003.

The World Bank and the Institute of Economic System & Management (2001). Modernizing China's oil and gas sector structure reform and regulation. *PRC* March 2001, pp. 216.

The World Bank, Institute of Economic System & Management, Public-private Infrastructure Advisory Facility (2002). China: Economic regulation of long-distance gas transmission and urban gas distribution. *PRC* August 2002, pp. 412.

USEPA et al (2005). Methane to Markets Partnership Coal Mine Methane Subcommittee Country Profile: United States of America, January 14, 2005.

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	Énergies modernes et réduction de la pauvreté: Un atelier multi-sectoriel. Actes de l'atelier régional. Douala, Cameroun du 16-18 juillet 2003. (French Only)	09/04	286/04
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Ghana	Energy Assessment (English)	11/86	6234-GH
	Energy Rationalization in the Industrial Sector (English)	06/88	084/88
	Sawmill Residues Utilization Study (English)	11/88	074/87
	Industrial Energy Efficiency (English)	11/92	148/92
	Corporatization of Distribution Concessions through Capitalization	12/03	272/03
Guinea	Energy Assessment (English)	11/86	6137-GUI
	Household Energy Strategy (English and French)	01/94	163/94
Guinea Bissau	Energy Assessment (English and Portuguese)	08/84	5083-GUB
	Recommended Technical Assistance Projects (English & Portuguese)	04/85	033/85
	Management Options for the Electric Power and Water Supply Subsectors (English)	02/90	100/90
	Power and Water Institutional Restructuring (French)	04/91	118/91
Kenya	Energy Assessment (English)	05/82	3800 KE
	Power System Efficiency Study (English)	03/84	014/84
	Status Report (English)	05/84	016/84
	Coal Conversion Action Plan (English)	02/87	–
Kenya	Solar Water Heating Study (English)	02/87	066/87
	Peri-Urban Woodfuel Development (English)	10/87	076/87
	Power Master Plan (English)	11/87	–
	Power Loss Reduction Study (English)	09/96	186/96
	Implementation Manual: Financing Mechanisms for Solar Electric Equipment	07/00	231/00
Lesotho	Energy Assessment (English)	01/84	4676-LSO
Liberia	Energy Assessment (English)	12/84	5279-LBR
	Recommended Technical Assistance Projects (English)	06/85	038/85
	Power System Efficiency Study (English)	12/87	081/87
Madagascar	Energy Assessment (English)	01/87	5700-MAG
	Power System Efficiency Study (English and French)	12/87	075/87
	Environmental Impact of Woodfuels (French)	10/95	176/95
Malawi	Energy Assessment (English)	08/82	3903-MAL
	Technical Assistance to Improve the Efficiency of Fuelwood Use in the Tobacco Industry (English)	11/83	009/83
	Status Report (English)	01/84	013/84
Mali	Energy Assessment (English and French)	11/91	8423-MLI
	Household Energy Strategy (English and French)	03/92	147/92
Islamic Republic of Mauritania	Energy Assessment (English and French)	04/85	5224-MAU
	Household Energy Strategy Study (English and French)	07/90	123/90
Mauritius	Energy Assessment (English)	12/81	3510-MAS
	Status Report (English)	10/83	008/83
	Power System Efficiency Audit (English)	05/87	070/87
	Bagasse Power Potential (English)	10/87	077/87
	Energy Sector Review (English)	12/94	3643-MAS
Mozambique	Energy Assessment (English)	01/87	6128-MOZ
	Household Electricity Utilization Study (English)	03/90	113/90
	Electricity Tariffs Study (English)	06/96	181/96
	Sample Survey of Low Voltage Electricity Customers	06/97	195/97
Namibia	Energy Assessment (English)	03/93	11320-NAM

Region/Country	Activity/Report Title	Date	Number
Niger	Energy Assessment (French)	05/84	4642-NIR
	Status Report (English and French)	02/86	051/86
	Improved Stoves Project (English and French)	12/87	080/87
	Household Energy Conservation and Substitution (English and French)	01/88	082/88
Nigeria	Energy Assessment (English)	08/83	4440-UNI
	Energy Assessment (English)	07/93	11672-UNI
	Strategic Gas Plan	02/04	279/04
Rwanda	Energy Assessment (English)	06/82	3779-RW
	Status Report (English and French)	05/84	017/84
	Improved Charcoal Cookstove Strategy (English and French)	08/86	059/86
	Improved Charcoal Production Techniques (English and French)	02/87	065/87
	Energy Assessment (English and French)	07/91	8017-RW
	Commercialization of Improved Charcoal Stoves and Carbonization Techniques Mid-Term Progress Report (English and French)	12/91	141/91
SADC	SADC Regional Power Interconnection Study, Vols. I-IV (English)	12/93	-
SADCC	SADCC Regional Sector: Regional Capacity-Building Program for Energy Surveys and Policy Analysis (English)	11/91	-
Sao Tome and Principe	Energy Assessment (English)	10/85	5803-STP
Senegal	Energy Assessment (English)	07/83	4182-SE
	Status Report (English and French)	10/84	025/84
Senegal	Industrial Energy Conservation Study (English)	05/85	037/85
	Preparatory Assistance for Donor Meeting (English and French)	04/86	056/86
	Urban Household Energy Strategy (English)	02/89	096/89
	Industrial Energy Conservation Program (English)	05/94	165/94
Seychelles	Energy Assessment (English)	01/84	4693-SEY
	Electric Power System Efficiency Study (English)	08/84	021/84
Sierra Leone	Energy Assessment (English)	10/87	6597-SL
Somalia	Energy Assessment (English)	12/85	5796-SO
Republic of South Africa	Options for the Structure and Regulation of Natural Gas Industry (English)	05/95	172/95
Sudan	Management Assistance to the Ministry of Energy and Mining	05/83	003/83
	Energy Assessment (English)	07/83	4511-SU
	Power System Efficiency Study (English)	06/84	018/84
	Status Report (English)	11/84	026/84
	Wood Energy/Forestry Feasibility (English)	07/87	073/87
Swaziland	Energy Assessment (English)	02/87	6262-SW
	Household Energy Strategy Study	10/97	198/97
Tanzania	Energy Assessment (English)	11/84	4969-TA
	Peri-Urban Woodfuels Feasibility Study (English)	08/88	086/88
	Tobacco Curing Efficiency Study (English)	05/89	102/89
	Remote Sensing and Mapping of Woodlands (English)	06/90	–
	Industrial Energy Efficiency Technical Assistance (English)	08/90	122/90
	Power Loss Reduction Volume 1: Transmission and Distribution System Technical Loss Reduction and Network Development (English)	06/98	204A/98
	Power Loss Reduction Volume 2: Reduction of Non-Technical Losses (English)	06/98	204B/98

Region/Country	Activity/Report Title	Date	Number
Togo	Energy Assessment (English)	06/85	5221-TO
	Wood Recovery in the Nangbeto Lake (English and French)	04/86	055/86
	Power Efficiency Improvement (English and French)	12/87	078/87
Uganda	Energy Assessment (English)	07/83	4453-UG
	Status Report (English)	08/84	020/84
	Institutional Review of the Energy Sector (English)	01/85	029/85
	Energy Efficiency in Tobacco Curing Industry (English)	02/86	049/86
	Fuelwood/Forestry Feasibility Study (English)	03/86	053/86
	Power System Efficiency Study (English)	12/88	092/88
	Energy Efficiency Improvement in the Brick and Tile Industry (English)	02/89	097/89
	Tobacco Curing Pilot Project (English)	03/89	UNDP Terminal Report
	Energy Assessment (English)	12/96	193/96
	Rural Electrification Strategy Study	09/99	221/99
Zaire	Energy Assessment (English)	05/86	5837-ZR
Zambia	Energy Assessment (English)	01/83	4110-ZA
	Status Report (English)	08/85	039/85
	Energy Sector Institutional Review (English)	11/86	060/86
	Power Subsector Efficiency Study (English)	02/89	093/88
	Energy Strategy Study (English)	02/89	094/88
	Urban Household Energy Strategy Study (English)	08/90	121/90
Zimbabwe	Energy Assessment (English)	06/82	3765-ZIM
	Power System Efficiency Study (English)	06/83	005/83
	Status Report (English)	08/84	019/84
	Power Sector Management Assistance Project (English)	04/85	034/85
Zimbabwe	Power Sector Management Institution Building (English)	09/89	–
	Petroleum Management Assistance (English)	12/89	109/89
	Charcoal Utilization Pre-feasibility Study (English)	06/90	119/90
	Integrated Energy Strategy Evaluation (English)	01/92	8768-ZIM
	Energy Efficiency Technical Assistance Project: Strategic Framework for a National Energy Efficiency Improvement Program (English)	04/94	–
	Capacity Building for the National Energy Efficiency Improvement Programme (NEEIP) (English)	12/94	–
	Rural Electrification Study	03/00	228/00
	Les réformes du secteur de l'électricite en Afrique: Evaluation de leurs conséquences pour les populations pauvres	11/06	306/06
	EAST ASIA AND PACIFIC (EAP)		
Asia Regional	Pacific Household and Rural Energy Seminar (English)	11/90	–
China	County-Level Rural Energy Assessments (English)	05/89	101/89
	Fuelwood Forestry Preinvestment Study (English)	12/89	105/89
	Strategic Options for Power Sector Reform in China (English)	07/93	156/93
	Energy Efficiency and Pollution Control in Township and Village Enterprises (TVE) Industry (English)	11/94	168/94
	Energy for Rural Development in China: An Assessment Based on a Joint Chinese/ESMAP Study in Six Counties (English)	06/96	183/96
	Improving the Technical Efficiency of Decentralized Power Companies	09/99	222/99

Region/Country	Activity/Report Title	Date	Number
	Air Pollution and Acid Rain Control: The Case of Shijiazhuang City and the Changsha Triangle Area	10/03	267/03
	Toward a Sustainable Coal Sector In China	07/04	287/04
	Demand Side Management in a Restructured Industry: How Regulation and Policy Can Deliver Demand-Side Management Benefits to a Growing Economy and a Changing Power System	12/05	314/05
	A Strategy for CBM and CMM Development and Utilization in China	07/07	326/07
Fiji	Energy Assessment (English)	06/83	4462-FIJ
Indonesia	Energy Assessment (English)	11/81	3543-IND
	Status Report (English)	09/84	022/84
	Power Generation Efficiency Study (English)	02/86	050/86
	Energy Efficiency in the Brick, Tile and Lime Industries (English)	04/87	067/87
	Diesel Generating Plant Efficiency Study (English)	12/88	095/88
	Urban Household Energy Strategy Study (English)	02/90	107/90
	Biomass Gasifier Preinvestment Study Vols. I & II (English)	12/90	124/90
	Prospects for Biomass Power Generation with Emphasis on Palm Oil, Sugar, Rubberwood and Plywood Residues (English)	11/94	167/94
Lao PDR	Urban Electricity Demand Assessment Study (English)	03/93	154/93
	Institutional Development for Off-Grid Electrification	06/99	215/99
Malaysia	Sabah Power System Efficiency Study (English)	03/87	068/87
	Gas Utilization Study (English)	09/91	9645-MA
Mongolia	Energy Efficiency in the Electricity and District Heating Sectors	10/01	247/01
	Improved Space Heating Stoves for Ulaanbaatar	03/02	254/02
	Impact of Improved Stoves on Indoor Air Quality in Ulaanbaatar, Mongolia	11/05	313/05
Myanmar	Energy Assessment (English)	06/85	5416-BA
Papua New Guinea	Energy Assessment (English)	06/82	3882-PNG
Papua New Guinea	Status Report (English)	07/83	006/83
	Institutional Review in the Energy Sector (English)	10/84	023/84
	Power Tariff Study (English)	10/84	024/84
Philippines	Commercial Potential for Power Production from Agricultural Residues (English)	12/93	157/93
	Energy Conservation Study (English)	08/94	–
	Strengthening the Non-Conventional and Rural Energy Development Program in the Philippines: A Policy Framework and Action Plan	08/01	243/01
	Rural Electrification and Development in the Philippines: Measuring the Social and Economic Benefits	05/02	255/02
Solomon Islands	Energy Assessment (English)	06/83	4404-SOL
	Energy Assessment (English)	01/92	979-SOL
South Pacific	Petroleum Transport in the South Pacific (English)	05/86	–
Thailand	Energy Assessment (English)	09/85	5793-TH
	Rural Energy Issues and Options (English)	09/85	044/85
	Accelerated Dissemination of Improved Stoves and Charcoal Kilns (English)	09/87	079/87
	Northeast Region Village Forestry and Woodfuels Preinvestment Study (English)	02/88	083/88

Region/Country	Activity/Report Title	Date	Number
	Impact of Lower Oil Prices (English)	08/88	–
	Coal Development and Utilization Study (English)	10/89	–
	Why Liberalization May Stall in a Mature Power Market: A Review of the Technical and Political Economy Factors that Constrained the Electricity Sector Reform in Thailand 1998-2002	12/03	270/03
	Reducing Emissions from Motorcycles in Bangkok	10/03	275/03
Tonga	Energy Assessment (English)	06/85	5498-TON
Vanuatu	Energy Assessment (English)	06/85	5577-VA
Vietnam	Rural and Household Energy-Issues and Options (English)	01/94	161/94
	Power Sector Reform and Restructuring in Vietnam: Final Report to the Steering Committee (English and Vietnamese)	09/95	174/95
	Household Energy Technical Assistance: Improved Coal Briquetting and Commercialized Dissemination of Higher Efficiency Biomass and Coal Stoves (English)	01/96	178/96
	Petroleum Fiscal Issues and Policies for Fluctuating Oil Prices In Vietnam	02/01	236/01
	An Overnight Success: Vietnam's Switch to Unleaded Gasoline	08/02	257/02
	The Electricity Law for Vietnam — Status and Policy Issues — The Socialist Republic of Vietnam	08/02	259/02
	Petroleum Sector Technical Assistance for the Revision of the Existing Legal and Regulatory Framework	12/03	269/03
Western Samoa	Energy Assessment (English)	06/85	5497-WSO
	SOUTH ASIA (SAS)		
Bangladesh	Energy Assessment (English)	10/82	3873-BD
	Priority Investment Program (English)	05/83	002/83
	Status Report (English)	04/84	015/84
	Power System Efficiency Study (English)	02/85	031/85
	Small Scale Uses of Gas Pre-feasibility Study (English)	12/88	–
	Reducing Emissions from Baby-Taxis in Dhaka	01/02	253/02
India	Opportunities for Commercialization of Non-conventional Energy Systems (English)	11/88	091/88
	Maharashtra Bagasse Energy Efficiency Project (English)	07/90	120/90
	Mini-Hydro Development on Irrigation Dams and Canal Drops Vols. I, II and III (English)	07/91	139/91
	WindFarm Pre-Investment Study (English)	12/92	150/92
	Power Sector Reform Seminar (English)	04/94	166/94
	Environmental Issues in the Power Sector (English)	06/98	205/98
	Environmental Issues in the Power Sector: Manual for Environmental Decision Making (English)	06/99	213/99
	Household Energy Strategies for Urban India: The Case of Hyderabad	06/99	214/99
	Greenhouse Gas Mitigation In the Power Sector: Case Studies From India	02/01	237/01
	Energy Strategies for Rural India: Evidence from Six States	08/02	258/02
	Household Energy, Indoor Air Pollution, and Health	11/02	261/02
	Access of the Poor to Clean Household Fuels	07/03	263/03
	The Impact of Energy on Women's Lives in Rural India	01/04	276/04
	Environmental Issues in the Power Sector: Long-Term Impacts And Policy Options for Rajasthan	10/04	292/04

Region/Country	Activity/Report Title	Date	Number
	Environmental Issues in the Power Sector: Long-Term Impacts And Policy Options for Karnataka	10/04	293/04
Nepal	Energy Assessment (English)	08/83	4474-NEP
	Status Report (English)	01/85	028/84
	Energy Efficiency & Fuel Substitution in Industries (English)	06/93	158/93
Pakistan	Household Energy Assessment (English)	05/88	–
	Assessment of Photovoltaic Programs, Applications, and Markets (English)	10/89	103/89
	National Household Energy Survey and Strategy Formulation Study: Project Terminal Report (English)	03/94	–
	Managing the Energy Transition (English)	10/94	–
	Lighting Efficiency Improvement Program Phase 1: Commercial Buildings Five Year Plan (English)	10/94	–
	Clean Fuels	10/01	246/01
	Household Use of Commercial Energy	05/06	320/06
Regional	Toward Cleaner Urban Air in South Asia: Tackling Transport Pollution, Understanding Sources.	03/04	281/04
Sri Lanka	Energy Assessment (English)	05/82	3792-CE
	Power System Loss Reduction Study (English)	07/83	007/83
	Status Report (English)	01/84	010/84
	Industrial Energy Conservation Study (English)	03/86	054/86
	Sustainable Transport Options for Sri Lanka: Vol. I	02/03	262/03
	Greenhouse Gas Mitigation Options in the Sri Lanka Power Sector: Vol. II	02/03	262/03
	Sri Lanka Electric Power Technology Assessment (SLEPTA): Vol. III	02/03	262/03
	Energy and Poverty Reduction: Proceedings from South Asia Practitioners Workshop How Can Modern Energy Services Contribute to Poverty Reduction? Colombo, Sri Lanka, June 2-4, 2003	11/03	268/03
	EUROPE AND CENTRAL ASIA (ECA)		
Armenia	Development of Heat Strategies for Urban Areas of Low-income Transition Economies. Urban Heating Strategy for the Republic Of Armenia. *Including a Summary of a Heating Strategy for the Kyrgyz Republic*	04/04	282/04
Bulgaria	Natural Gas Policies and Issues (English)	10/96	188/96
	Energy Environment Review	10/02	260/02
Central Asia and The Caucasus	Cleaner Transport Fuels in Central Asia and the Caucasus	08/01	242/01
Central and Eastern Europe	Power Sector Reform in Selected Countries	07/97	196/97
	Increasing the Efficiency of Heating Systems in Central and Eastern Europe and the Former Soviet Union (English and Russian)	08/00	234/00
	The Future of Natural Gas in Eastern Europe (English)	08/92	149/92
Kazakhstan	Natural Gas Investment Study, Volumes 1, 2 & 3	12/97	199/97
Kazakhstan & Kyrgyzstan	Opportunities for Renewable Energy Development	11/97	16855-KAZ
Poland	Energy Sector Restructuring Program Vols. I-V (English)	01/93	153/93
	Natural Gas Upstream Policy (English and Polish)	08/98	206/98
	Energy Sector Restructuring Program: Establishing the Energy		

Region/Country	Activity/Report Title	Date	Number
	Regulation Authority	10/98	208/98
Portugal	Energy Assessment (English)	04/84	4824-PO
Romania	Natural Gas Development Strategy (English)	12/96	192/96
	Private Sector Participation in Market-Based Energy-Efficiency Financing Schemes: Lessons Learned from Romania and International Experiences.	11/03	274/03
Slovenia	Workshop on Private Participation in the Power Sector (English)	02/99	211/99
Turkey	Energy Assessment (English)	03/83	3877-TU
	Energy and the Environment: Issues and Options Paper	04/00	229/00
	Energy and Environment Review: Synthesis Report	12/03	273/03
	Turkey's Experience with Greenfield Gas Distribution since 2003	03/07	325/05

MIDDLE EAST AND NORTH AFRICA (MENA)

Region/Country	Activity/Report Title	Date	Number
Turkey	Turkey's Experience with Greenfield Gas Distribution since 2003	05/07	325/07
Arab Republic of Egypt	Energy Assessment (English)	10/96	189/96
	Energy Assessment (English and French)	03/84	4157-MOR
	Status Report (English and French)	01/86	048/86
Morocco	Energy Sector Institutional Development Study (English and French)	07/95	173/95
	Natural Gas Pricing Study (French)	10/98	209/98
	Gas Development Plan Phase II (French)	02/99	210/99
Syria	Energy Assessment (English)	05/86	5822-SYR
	Electric Power Efficiency Study (English)	09/88	089/88
	Energy Efficiency Improvement in the Cement Sector (English)	04/89	099/89
	Energy Efficiency Improvement in the Fertilizer Sector (English)	06/90	115/90
Tunisia	Fuel Substitution (English and French)	03/90	–
	Power Efficiency Study (English and French)	02/92	136/91
	Energy Management Strategy in the Residential and Tertiary Sectors (English)	04/92	146/92
	Renewable Energy Strategy Study, Volume I (French)	11/96	190A/96
	Renewable Energy Strategy Study, Volume II (French)	11/96	190B/96
	Rural Electrification in Tunisia: National Commitment, Efficient Implementation and Sound Finances	08/05	307/05
Yemen	Energy Assessment (English)	12/84	4892-YAR
	Energy Investment Priorities (English)	02/87	6376-YAR
	Household Energy Strategy Study Phase I (English)	03/91	126/91
	Household Energy Supply and Use in Yemen. Volume I: Main Report and Volume II: Annexes	12/05	315/05

LATIN AMERICA AND THE CARIBBEAN REGION (LCR)

Region/Country	Activity/Report Title	Date	Number
LCR Regional	Regional Seminar on Electric Power System Loss Reduction in the Caribbean (English)	07/89	–
	Elimination of Lead in Gasoline in Latin America and the Caribbean (English and Spanish)	04/97	194/97
	Elimination of Lead in Gasoline in Latin America and the Caribbean - Status Report (English and Spanish)	12/97	200/97
	Harmonization of Fuels Specifications in Latin America and the Caribbean (English and Spanish)	06/98	203/98
	Energy and Poverty Reduction: Proceedings from the Global Village		

Region/Country	Activity/Report Title	Date	Number
	Energy Partnership (GVEP) Workshop held in Bolivia	06/05	202/05
	Power Sector Reform and the Rural Poor in Central America	12/04	297/04
	Estudio Comparativo Sobre la Distribución de la Renta Petrolera en Bolivia, Colombia, Ecuador y Perú	08/05	304/05
	OECS Energy Sector Reform and Renewable Energy/Energy Efficiency Options	02/06	317/06
	The Landfill Gas-to-Energy Initiative for Latin America and the Caribbean	02/06	318/06
Bolivia	Energy Assessment (English)	04/83	4213-BO
	National Energy Plan (English)	12/87	–
	La Paz Private Power Technical Assistance (English)	11/90	111/90
	Pre-feasibility Evaluation Rural Electrification and Demand Assessment (English and Spanish)	04/91	129/91
	National Energy Plan (Spanish)	08/91	131/91
	Private Power Generation and Transmission (English)	01/92	137/91
	Natural Gas Distribution: Economics and Regulation (English)	03/92	125/92
	Natural Gas Sector Policies and Issues (English and Spanish)	12/93	164/93
	Household Rural Energy Strategy (English and Spanish)	01/94	162/94
	Preparation of Capitalization of the Hydrocarbon Sector	12/96	191/96
	Introducing Competition into the Electricity Supply Industry in Developing Countries: Lessons from Bolivia	08/00	233/00
	Final Report on Operational Activities Rural Energy and Energy Efficiency	08/00	235/00
	Oil Industry Training for Indigenous People: The Bolivian Experience (English and Spanish)	09/01	244/01
	Capacitación de Pueblos Indígenas en la Actividad Petrolera. Fase II	07/04	290/04
Boliva-Brazil	Best Practices in Mainstreaming Environmental & Social Safeguards Into Gas Pipeline Projects	07/06	322/06
	Estudio Sobre Aplicaciones en Pequeña Escala de Gas Natural	07/04	291/04
Brazil	Energy Efficiency & Conservation: Strategic Partnership for Energy Efficiency in Brazil (English)	01/95	170/95
	Hydro and Thermal Power Sector Study	09/97	197/97
	Rural Electrification with Renewable Energy Systems in the Northeast: A Preinvestment Study	07/00	232/00
	Reducing Energy Costs in Municipal Water Supply Operations	07/03	265/03
	"Learning-while-doing" Energy M&T on the Brazilian Frontlines		
Chile	Energy Sector Review (English)	08/88	7129-CH
Colombia	Energy Strategy Paper (English)	12/86	–
	Power Sector Restructuring (English)	11/94	169/94
	Energy Efficiency Report for the Commercial and Public Sector (English)	06/96	184/96
Costa Rica	Energy Assessment (English and Spanish)	01/84	4655-CR
	Recommended Technical Assistance Projects (English)	11/84	027/84
	Forest Residues Utilization Study (English and Spanish)	02/90	108/90
Dominican Republic	Energy Assessment (English)	05/91	8234-DO
Ecuador	Energy Assessment (Spanish)	12/85	5865-EC
	Energy Strategy Phase I (Spanish)	07/88	–
	Energy Strategy (English)	04/91	–
	Private Mini-hydropower Development Study (English)	11/92	–

Region/Country	Activity/Report Title	Date	Number
	Energy Pricing Subsidies and Interfuel Substitution (English)	08/94	11798-EC
	Energy Pricing, Poverty and Social Mitigation (English)	08/94	12831-EC
Guatemala	Issues and Options in the Energy Sector (English)	09/93	12160-GU
	Health Impacts of Traditional Fuel Use	08/04	284/04
Haiti	Energy Assessment (English and French)	06/82	3672-HA
	Status Report (English and French)	08/85	041/85
	Household Energy Strategy (English and French)	12/91	143/91
Honduras	Energy Assessment (English)	08/87	6476-HO
	Petroleum Supply Management (English)	03/91	128/91
Jamaica	Energy Assessment (English)	04/85	5466-JM
	Petroleum Procurement, Refining, and Distribution Study (English)	11/86	061/86
	Energy Efficiency Building Code Phase I (English)	03/88	–
	Energy Efficiency Standards and Labels Phase I (English)	03/88	–
	Management Information System Phase I (English)	03/88	–
	Charcoal Production Project (English)	09/88	090/88
	FIDCO Sawmill Residues Utilization Study (English)	09/88	088/88
	Energy Sector Strategy and Investment Planning Study (English)	07/92	135/92
Mexico	Improved Charcoal Production Within Forest Management for the State of Veracruz (English and Spanish)	08/91	138/91
	Energy Efficiency Management Technical Assistance to the Comisión Nacional para el Ahorro de Energía (CONAE) (English)	04/96	180/96
	Energy Environment Review	05/01	241/01
	Proceedings of the International Grid-Connected Renewable Energy Policy Forum (with CD)	08/06	324/06
Nicaragua	Modernizing the Fuelwood Sector in Managua and León	12/01	252/01
	Policy & Strategy for the Promotion of RE Policies in Nicaragua. (Contains CD with 3 complementary reports)	01/06	316/06
Panama	Power System Efficiency Study (English)	06/83	004/83
Paraguay	Energy Assessment (English)	10/84	5145-PA
	Recommended Technical Assistance Projects (English)	09/85	
	Status Report (English and Spanish)	09/85	043/85
	Reforma del Sector Hidrocarburos (Spanish Only)	03/06	319/06
Peru	Energy Assessment (English)	01/84	4677-PE
	Status Report (English)	08/85	040/85
	Proposal for a Stove Dissemination Program in the Sierra (English and Spanish)	02/87	064/87
	Energy Strategy (English and Spanish)	12/90	–
Peru	Study of Energy Taxation and Liberalization of the Hydrocarbons Sector (English and Spanish)	120/93	159/93
	Reform and Privatization in the Hydrocarbon Sector (English and Spanish)	07/99	216/99
	Rural Electrification	02/01	238/01
Saint Lucia	Energy Assessment (English)	09/84	5111-SLU
St. Vincent and the Grenadines	Energy Assessment (English)	09/84	5103-STV
Sub Andean	Environmental and Social Regulation of Oil and Gas		

Region/Country	Activity/Report Title	Date	Number
	Operations in Sensitive Areas of the Sub-Andean Basin (English and Spanish)	07/99	217/99
Trinidad and Tobago	Energy Assessment (English)	12/85	5930-TR
	GLOBAL		
	Energy End Use Efficiency: Research and Strategy (English)	11/89	–
	Women and Energy -A Resource Guide The International Network: Policies and Experience (English)	04/90	–
	Guidelines for Utility Customer Management and Metering (English and Spanish)	07/91	–
	Assessment of Personal Computer Models for Energy Planning in Developing Countries (English)	10/91	–
	Long-Term Gas Contracts Principles and Applications (English)	02/93	152/93
	Comparative Behavior of Firms Under Public and Private Ownership (English)	05/93	155/93
	Development of Regional Electric Power Networks (English)	10/94	–
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	Private Financing for Community Infrastructure	05/02	256/02
	Stakeholder Involvement in Options Assessment: Promoting Dialogue in Meeting Water and Energy Needs: A Sourcebook	07/03	264/03
	A Review of ESMAP's Energy Efficiency Portfolio	11/03	271/03
	A Review of ESMAP's Rural Energy and Renewable Energy Portfolio	04/04	280/04
	ESMAP Renewable Energy and Energy Efficiency Reports 1998-2004 (CD Only)	05/04	283/04
	Regulation of Associated Gas Flaring and Venting: A Global Overview and Lessons Learned from International Experience	08/04	285/04
	ESMAP Gender in Energy Reports and Other related Information (CD Only)	11/04	288/04
	ESMAP Indoor Air Pollution Reports and Other related Information (CD Only)	11/04	289/04
	Energy and Poverty Reduction: Proceedings from the Global Village Energy Partnership (GVEP) Workshop on the Pre-Investment Funding. Berlin, Germany, April 23-24, 2003.	11/04	294/04
	Global Village Energy Partnership (GVEP) Annual Report 2003	12/04	295/04
	Energy and Poverty Reduction: Proceedings from the Global Village Energy Partnership (GVEP) Workshop on Consumer Lending and Microfinance to Expand Access to Energy Services, Manila, Philippines, May 19-21, 2004	12/04	296/04
	The Impact of Higher Oil Prices on Low Income Countries And on the Poor	03/05	299/05
	Advancing Bioenergy for Sustainable Development: Guideline For Policymakers and Investors	04/05	300/05
	ESMAP Rural Energy Reports 1999-2005	03/05	301/05
	Renewable Energy and Energy Efficiency Financing and Policy Network: Options Study and Proceedings of the International Forum	07/05	303/05
	Implementing Power Rationing in a Sensible Way: Lessons Learned and International Best Practices	08/05	305/05
	The Urban Household Energy Transition. Joint Report with RFF Press/ESMAP. ISBN 1-933115-07-6	08/05	309/05
	Pioneering New Approaches in Support of Sustainable Development In the Extractive Sector: Community Development Toolkit, also Includes a CD containing Supporting Reports	10/05	310/05
	Analysis of Power Projects with Private Participation Under Stress	10/05	311/05
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