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Coal Bed Methane

CBM Sector Overview

- This report gives an overview of the CBM industry covering project development, technology, economics, markets and investment opportunities. It focuses primarily on the United States and Australia, but also examines emerging markets such as India and China.
- As exploration for oil and gas resources becomes increasingly difficult, companies are looking to unconventional resources to replace reserves and develop new sources of production.
- Coal bed methane (CBM) has made the transition from being a marginal resource and is now a respected mainstream source of gas in some countries.
- In the United States, CBM accounts for almost 10% of total domestic production. In Queensland Australia, CBM accounts for 30% of production. Now other countries are seeking to replicate this success and develop their CBM potential.

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Executive Summary

Coal bed methane (CBM) is gas which is created during the formation of coal and is trapped within a coal seam by formation water. CBM is chemically identical to other sources of gas, but is produced by non-conventional methods. CBM is generally more than 95% methane and is often marketed as being "green" as it contains no sulphur compounds such as hydrogen sulphide.

The production of methane from coal seams broadly falls into three project types: coal bed methane, coal mine methane and enhanced coal bed methane. Each project type presents different opportunities and issues to those involved.

CBM projects follow a multi-phase development process. This is because the majority of these projects are undertaken by small companies with limited capital resources and a phased approach mitigates against any potential risk.

Research and development have been key in the progression of CBM in recent years. One of the main drivers was cost reduction, a key factor for small companies. As a result, a lot of the technology and techniques developed are very company specific. In many cases, items such as gas gathering systems, have been developed in-house and are not found in any other development. More standard items such as compressors are bought off the shelf and the associated costs are more typical. However, as the industry matures, approaches and technologies are converging and are becoming more common.

Due to its unconventional nature, CBM producers initially had difficulties persuading gas purchasers to enter into contracts. This was mainly achieved by undercutting existing suppliers by offering discounted gas prices. As CBM became more established, companies were able to reduce the discount while still remaining competitive with conventional sources. By adopting this strategy CBM has managed to develop significant market share and in some regions it is seen to be a significant threat to conventional gas players.

As CBM becomes more widespread (particularly in the USA and Australia), a number of issues are impacting the industry. The issues include: water disposal, land access, licensing and methane loss to atmosphere. These issues are likely to be overcome and should not affect the long term viability of the industry.

The success of CBM in the US and Australia has prompted other countries to examine their CBM potential. Growing acceptance by the gas market has seen the perception of CBM shift from being unconventional to mainstream.

Since companies involved in CBM tend to be small with limited resources, it is imperative that they are able to develop fields in a cost effective way. The nature of developments (initially capital intensive drilling programme followed by long lead times before commercial production rates) means that companies are unable to generate positive cash flow for a number of years.

CBM is an attractive industry for upstream companies to be involved in and a number of opportunities exist for those wishing to invest in the sector.

CBM Overview

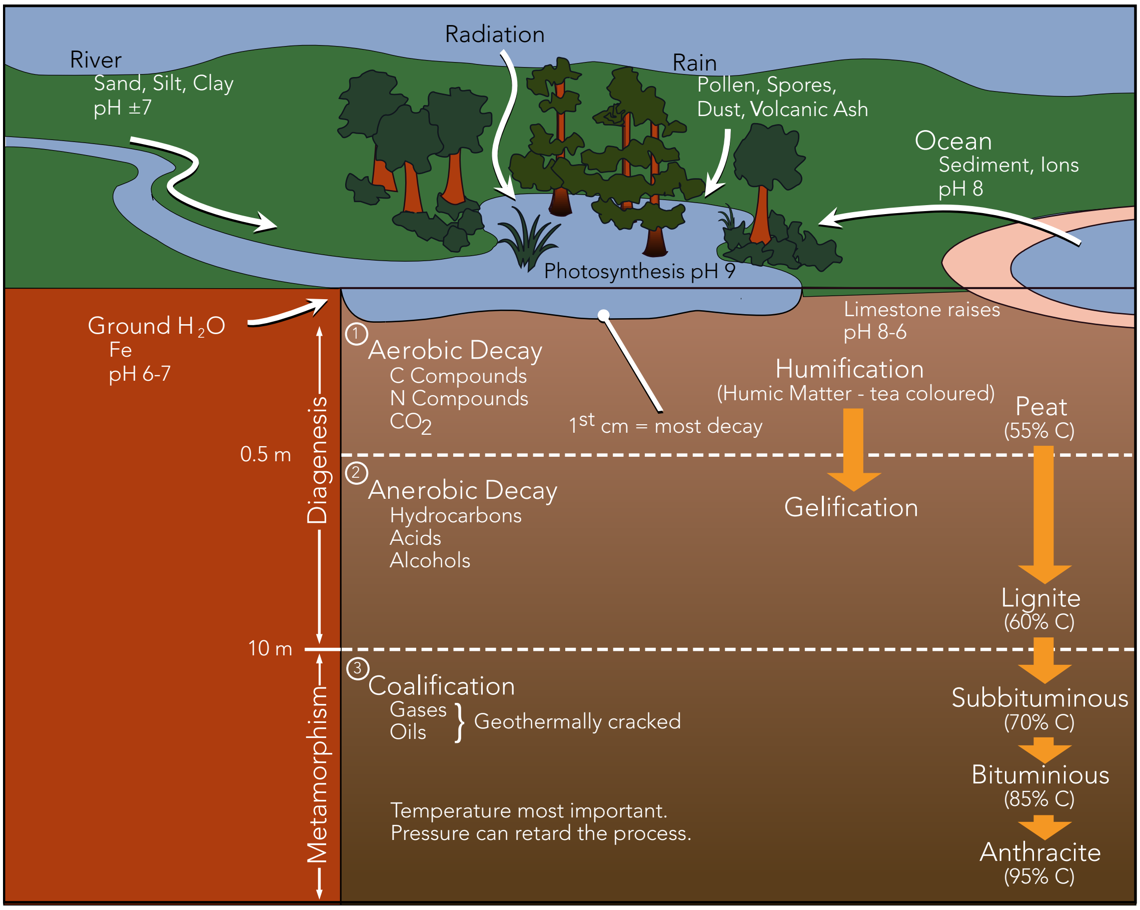
Coal bed methane (CBM) is gas which is created during the formation of coal and is trapped within a coal seam by formation water. CBM is chemically identical to other sources of gas, but is produced by non-conventional methods. CBM is generally more than 95% methane and is often marketed as being "green" as it contains no sulphur compounds such as hydrogen sulphide.

Formation of Coal and CBM

Formation of Coal

Coal is formed from biomass that has decayed, been compacted, hardened, chemically altered and metamorphosed by heat and pressure over geologic time. This process is known as coalification.

Exhibit 1: Coalification Process



Source: www.smtc.com

Coalification starts when biomass is deposited in swamp ecosystems with anaerobic aquatic environments. The low oxygen levels prevent complete decay by bacteria and oxidation. In order to form economically viable coal deposits, large volumes of undecayed organic matter must be preserved in an environment which remains steady for prolonged periods of time. The waters feeding the swamps must remain essentially free of sediment. This requires minimal erosion in the uplands of the tributary rivers and efficient trapping of the sediments.

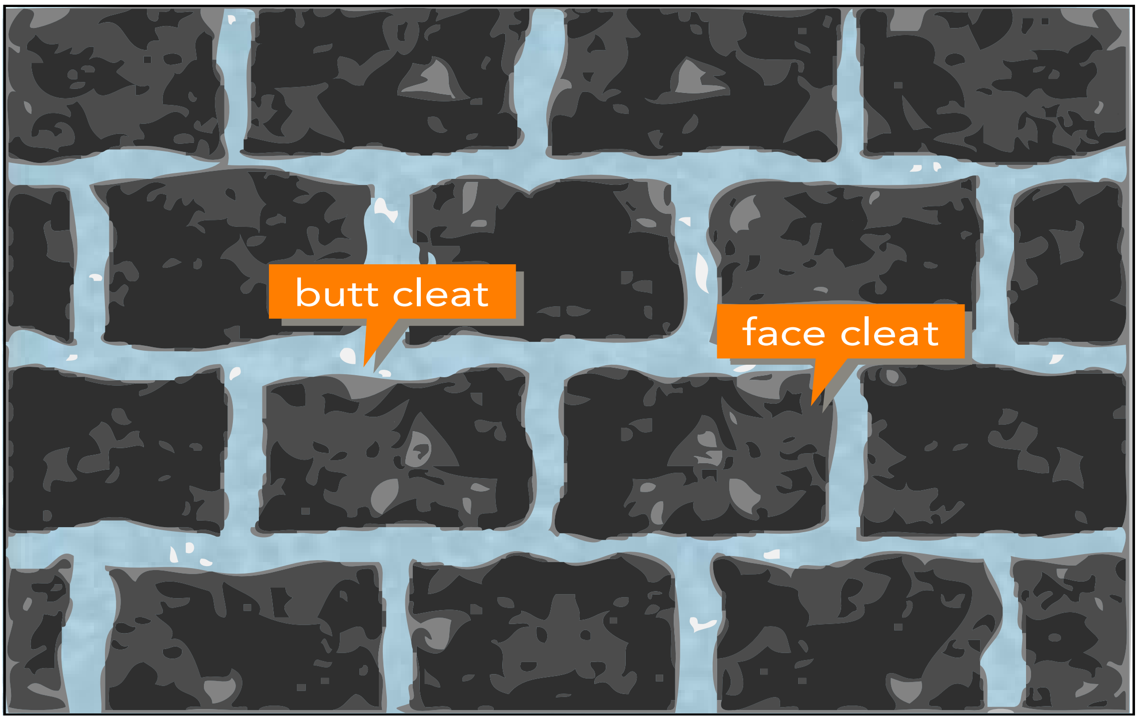
Eventually the coal forming environment is disturbed, usually by the onset of tectonic events. These events usually bring an abrupt end to the biomass deposition. A distinct upper contact with the overlying sediments is found in most coal seams, which indicates that the onset of further sediment deposition quickly destroyed the swamp ecosystem and replaced it with meandering stream and river environments during ongoing subsidence.

Formation of Methane in Coal

The gas methane is another component of coal, produced either by biogenic (by microbes) or thermogenic (by heat) routes. The methane produced during these processes is adsorped (the chemical binding of a gas onto the surface of a solid) onto the surface of the coal and is held in place by the pressure of the water contained within the coal. Should the water pressure drop, the methane separates from the coal surface and is lost to the atmosphere.

Underground coal is subjected to compression by over lying rock (known as overburden). This results in fractures known as cleats within the coal. These cleats form an interconnected fracture network and this allows water and gas to flow through the coal. However, CBM companies frequently use fracturing techniques to increase the permeability of the coal and increase flow rates.

Exhibit 2: Coal Cleat and Fracture Network

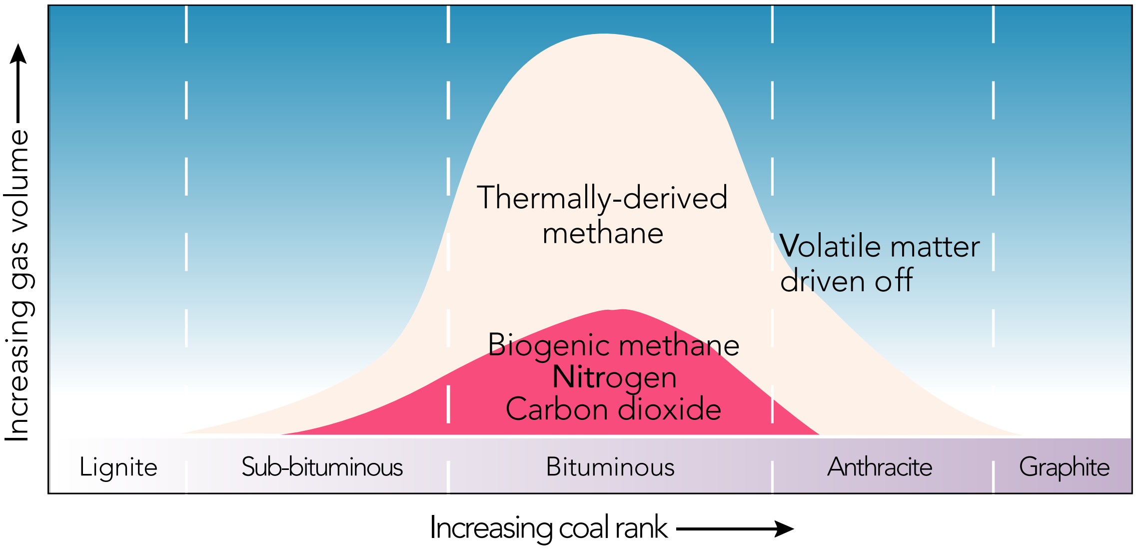


Source: www.ch4.com.au

Characteristics of Coal Suitable for CBM Production

Only certain ranks of coal are suitable for CBM production. Methane generation is a function of maceral (microscopic organic constituents which make up coal) type and the thermal maturation process. As temperature and pressure increase, the rank of the coal changes along with its ability to generate and store methane. Each maceral type adsorbs different volumes of methane and the ability for coal to store methane increases with rank.

Exhibit 3: Coal Gas Content by Rank



Source: Oilfield Review, Autumn 2003

Typically, coal suitable for CBM development has the following characteristics:

1. High gas content: $15m^3$ - $30m^3$ per ton is typical.
2. Good permeability: 30mD - 50mD is typical.
3. Shallow: Coal seams are less than 1,000m in depth. The pressure at greater depths is often too high to allow gas flow even when the seam has been completely dewatered. This is because the high pressure causes the cleat structure to close, reducing permeability.
4. Coal rank: Most CBM projects produce gas from Bituminous coals, but it can be possible to access gas in Anthracite.

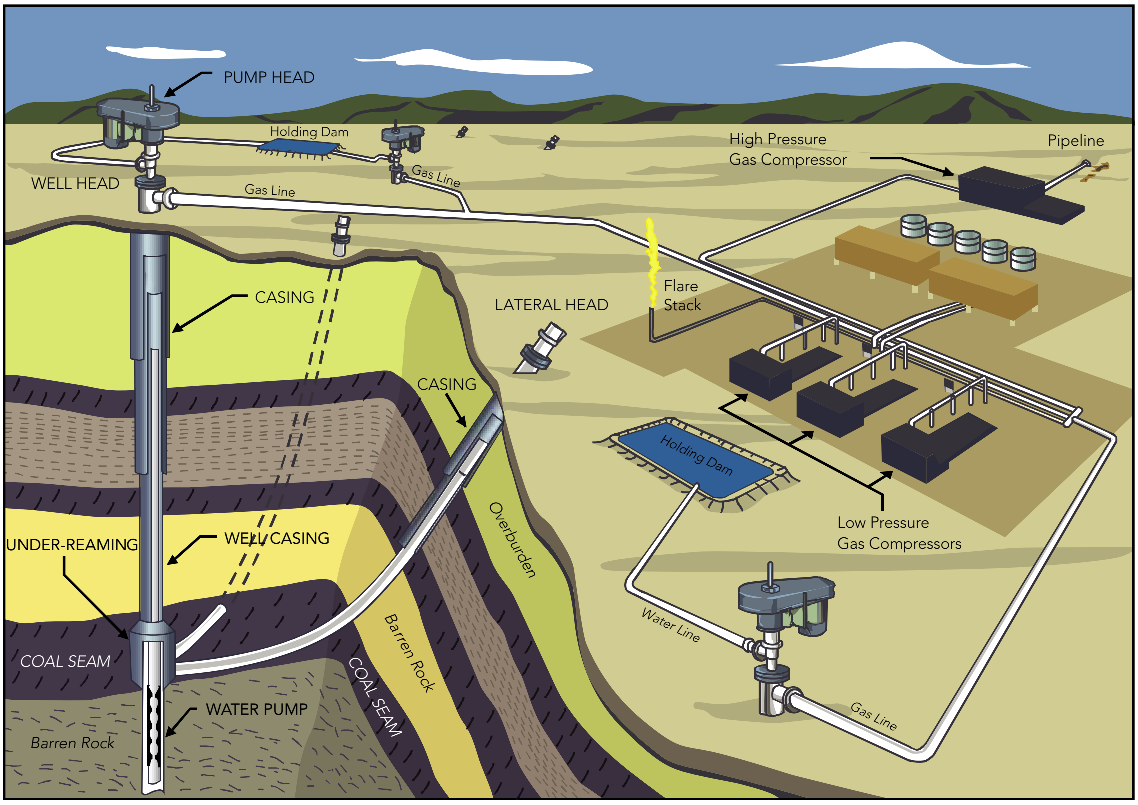
Development of Unconventional Gas Resources from Coal

The production of methane from coal seams broadly falls into three project types: coal bed methane, coal mine methane and enhanced coal bed methane. Each project type presents different opportunities and issues to those involved.

Coal Bed Methane (CBM)

CBM is also known as coal seam gas (CSG) or coal seam natural gas (CSNG). These names are used interchangeably, but all refer to projects where coal is dewatered resulting in the production of gas at the surface. In these projects, once the gas ceases to be produced then the development is usually abandoned i.e. the coal is not produced.

Exhibit 4: Typical CBM Development

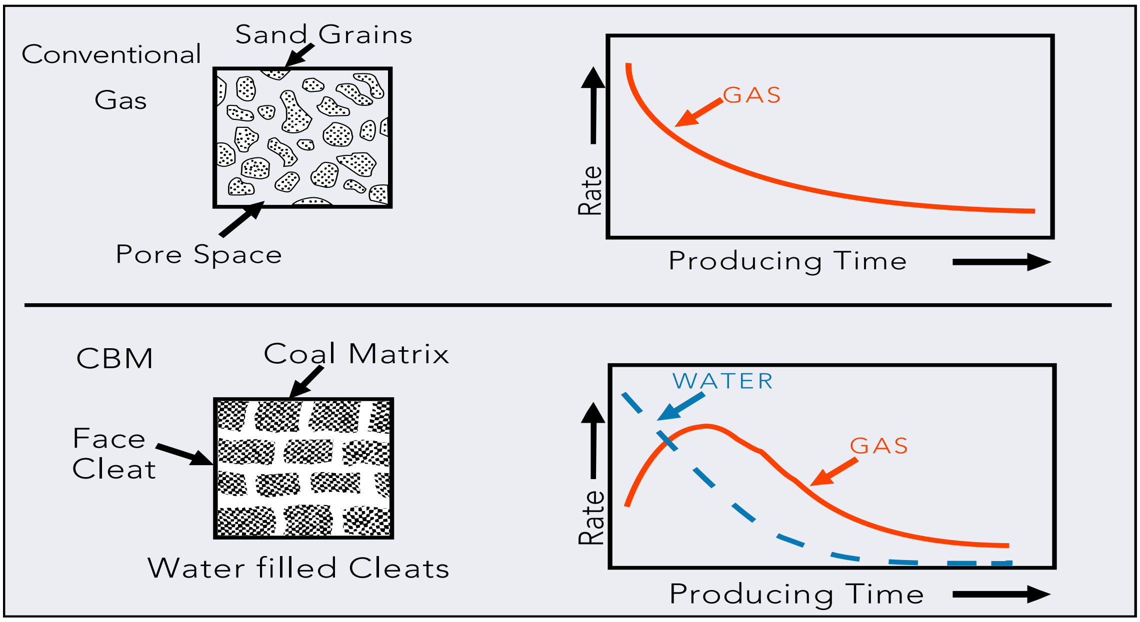


Source: www.ch4.com.au

CBM is an unconventional resource, but parallels can be drawn between it and conventional gas developments. In a conventional gas reservoir, gas is trapped within the structure of a porous rock at high pressure. A production well penetrates the reservoir and the pressure forces gas to the surface. Over time, gas diffuses via the pore spaces in the rock until the energy of the reservoir reduces to a point where production ceases. Gas production is highest at the start of the field's life and declines over time.

In a CBM reservoir, gas is adsorbed to the surface of the coal and is held in place by the pressure of the formation water. A production well penetrates the seam causing the water to be produced due to the pressure within the coal seam. During the initial period the well only produces water, but over time less water is produced and increasing volumes of gas are produced. Each well has an effective radius from which it can dewater the coal and produce gas. Gas production will eventually peak and subsequently go into decline.

Exhibit 5: Comparison of Conventional and CBM Reservoirs and Production

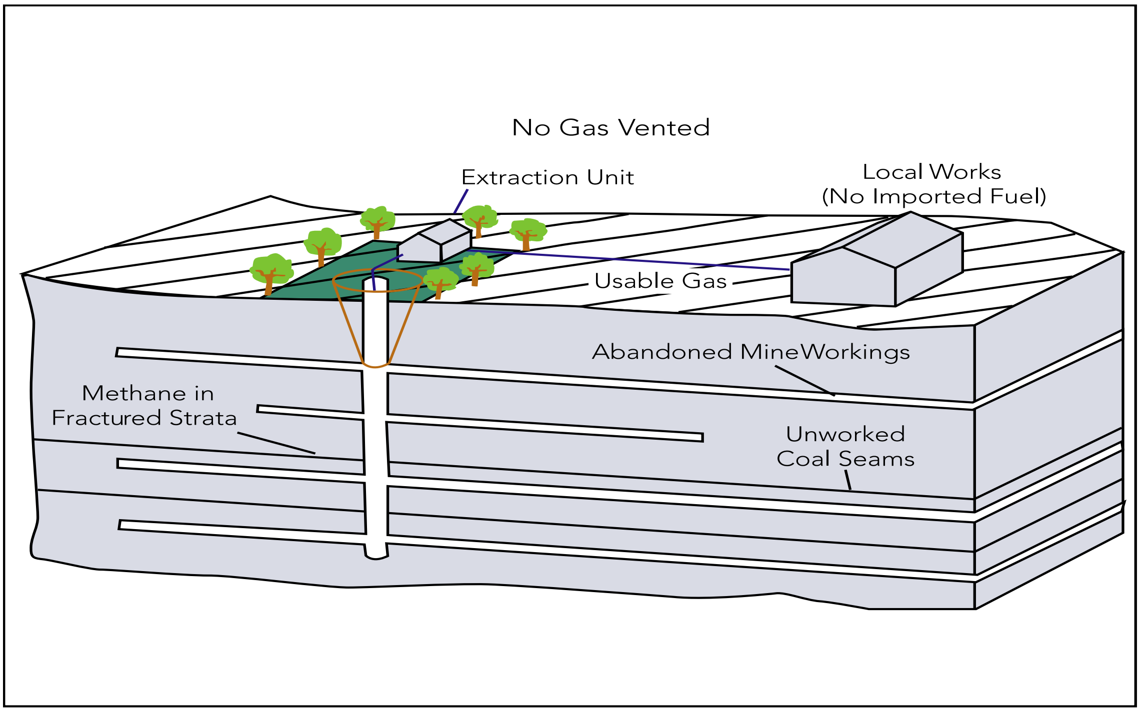


Source: US Department of Energy

Coal Mine Methane (CMM)

CMM projects are performed prior to (or during) the production of coal reserves. This is often done as a safety precaution as the build up of methane is a safety hazard. The methane that is produced is often used on site for power generation, but can also be sold into the gas market.

Exhibit 6: Typical CMM Development



Source: IEA

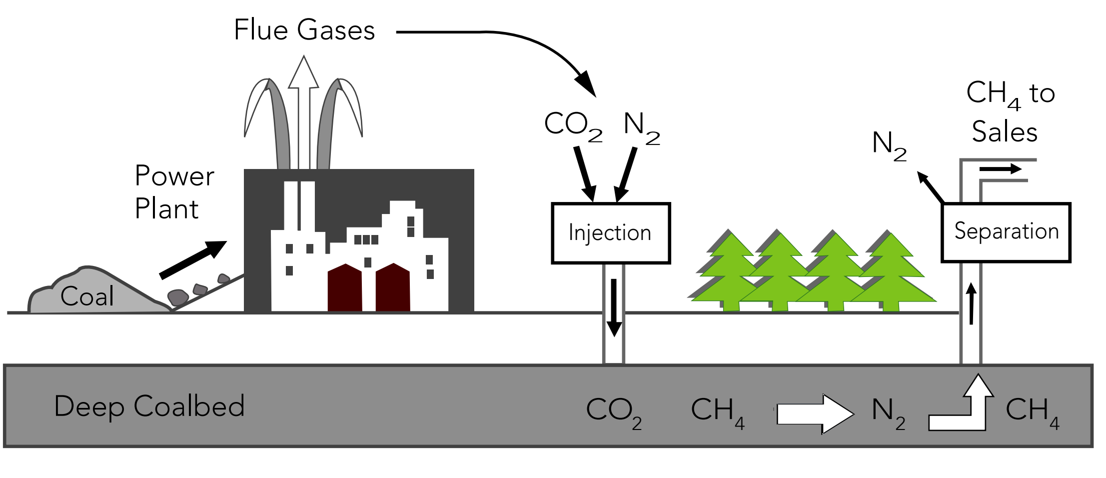
Enhanced CBM (ECBM)

Coal has double the affinity to adsorb carbon dioxide as it does for methane. This means that two molecules of carbon dioxide can displace one molecule of methane. ECBM provides an alternative mechanism for the production of methane. In this case instead of dewatering the coal, carbon dioxide is injected directly into the seam causing the displacement of methane. There are two benefits of doing this:

1. The lead time before the production of economic flows of methane is significantly reduced.. as dewatering can take up to two years prior to economic flow rates.
2. Carbon dioxide can be sequestered and therefore carbon credits can be generated and then traded. Also, in countries such as Norway where carbon dioxide taxes exist, sequestration can be a tax mitigation tool.

ECBM is still at the pilot stage of development, but it is seen as potentially important carbon sequestration methodology.

Exhibit 7: Typical ECBM Development



Enhanced coalbed methane recovery with sequestration of CO_2

Source: IEA

CBM Project Development

CBM projects follow a multi-phase development process. This is because the majority of these projects are undertaken by small companies with limited capital resources and a phased approach mitigates against any potential risk.

CBM projects typically go through the following stages of development:

1. Exploration
2. Geology & geophysics
3. Pilot project
4. Phased development
5. Abandonment

The location of coal reserves is well known. However, not all of these reserves are suitable for CBM development. A company will undertake an exploration programme to identify coal reserves suitable for development. The company will drill a series of core wells to obtain samples of coal which will then be tested. This programme should identify an area of coal that can economically produce CBM.

A full geology and geophysical analysis of the core samples will then be undertaken. This will test for several things including: gas content, permeability and seam thickness. If the results are positive then the project will move onto the pilot stage.

The key objective for the pilot project is to test that a prospect is economic to produce. Production wells are drilled over a limited area of the prospect. The performance of the wells will be used to build a production model and this model will determine the well spacing and therefore the number of wells required for full development. The pilot project also provides an opportunity to test techniques and technology. At this stage an initial reserve certification may occur. This certification can assist gas marketing activities and also help the company to secure additional capital.

Following a successful pilot project a full development of the project will start. This will normally occur in a number of stages, with each stage aiming to increase production in order to meet gas contract obligations. The phased approach also allows the company to generate revenues prior to capital expenditure in the next stage.

Once the economic production limit of the field is reached, it will then be abandoned. Most companies are only interested in the gas resource so the coal will not be produced. The energy content of the coal is not adversely affected by CBM production as most of the methane is lost during mining and pulverisation.

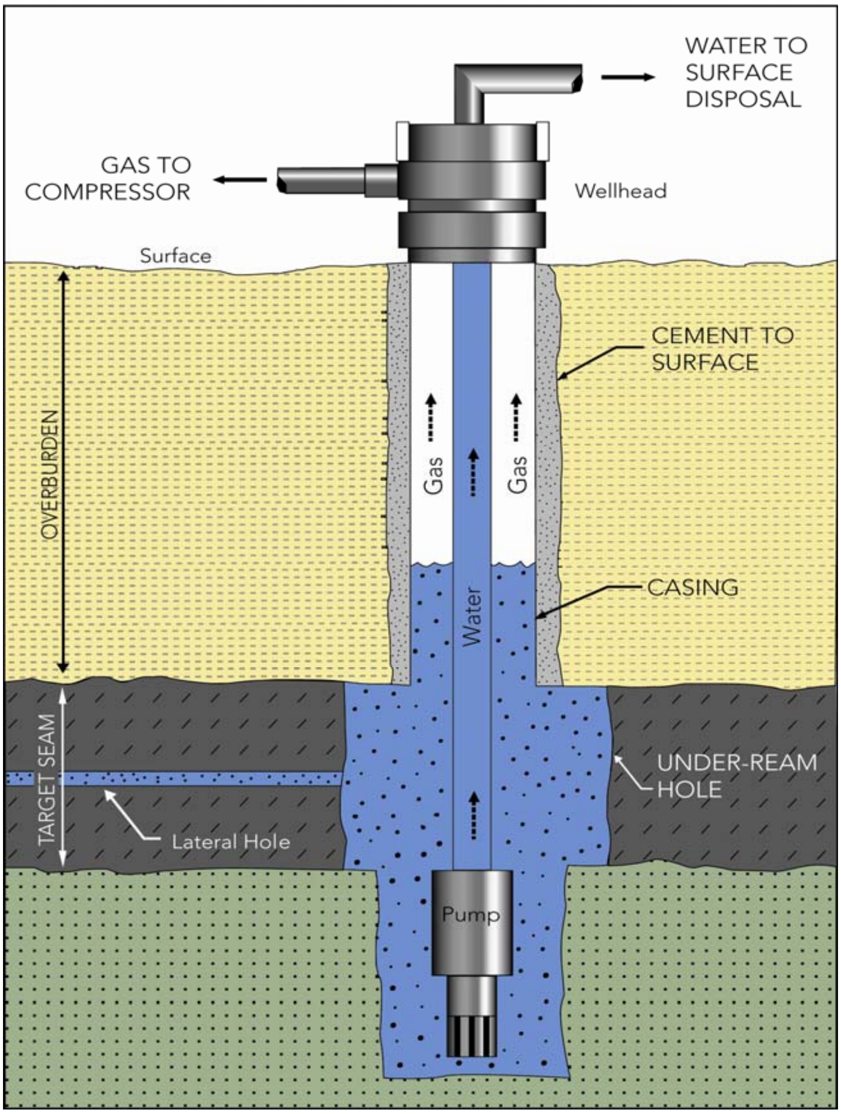
CBM Technology

Research and development have been key in the progression of CBM in recent years. One of the main drivers was cost reduction, a key factor for small companies. As a result, a lot of the technology and techniques developed are very company specific. In many cases, items such as gas gathering systems, have been developed in-house and are not found in any other development. More standard items such as compressors are bought off the shelf and the associated costs are more typical. However, as the industry matures, approaches and technologies are converging and are becoming more common.

Drilling

Unlike conventional gas, which is found at depths up to 7,000m, CBM is typically found at depths of 400m – 1,000m. These shallower depths make it possible to use smaller, more mobile, truck-mounted drilling rigs compared with those used for conventional gas wells. These types of rigs have much lower costs and therefore improve the project economics.

Exhibit 8: Downhole Well Schematic

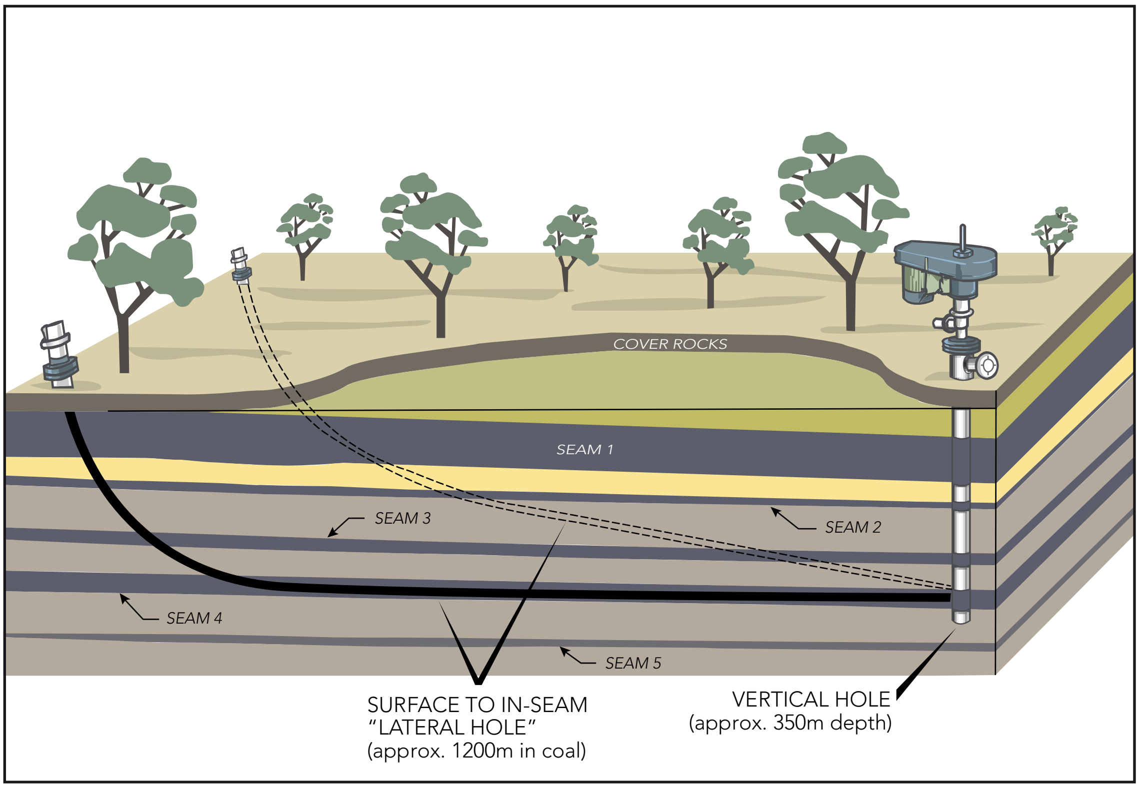


Source: www.ch4.com.au

The majority of projects use vertical drilling to develop fields. These wells are drilled down and through the seam (sometimes multiple seams are penetrated if this is deemed economic). Each well has an effective radius of gas drainage. Therefore, it is important to model the well spacing to ensure that the optimal volume of gas can be accessed. It is typical for a CBM project to require hundreds of vertical wells to be drilled over its lifetime. Advances in horizontal drilling techniques mean that it is now being implemented in suitable projects where it is cost effective.

The key advantage of horizontal wells is that fewer wells are required relative to vertical wells. Horizontal wells are able to track coal seams and so they can access more coal and produce more gas. Horizontal wells can also be used where land access is an issue as they can pass under disputed areas. The main drawbacks with horizontal wells are: they are technically more difficult to drill and are more expensive than vertical wells.

Exhibit 9: Typical Stratigraphic Section and Lateral Well Trajectory



Source: www.ch4.com.au

Hydraulic Fracturing

Hydraulic fracturing (more commonly known as "fracing") is the technique used to increase the surface area of the coal. The fluid systems and additives used in conventional wells are generally not suitable for CBM wells. This is because coal seam reservoirs have unique properties and therefore specially developed materials need to be used.

Fluids such as: water, foams and cross-linked polymers are pumped into the seam at high pressure. This causes the seam's internal pressure to increase, resulting in more cleats being formed in the coal. Consequently, the interconnected fracture network increases, making the coal more permeable resulting in increased gas flow rates and overall recovery factor.

Well Completion

CBM wells can utilise conventional methods of casing, cementing and perforating. However, care must be taken when casing is set and cemented across the coal seams in order to avoid permeability damage to the cleat network. Cleats are often wide enough to accept cement slurry, not just cement filtrate. Any damage caused by the slurry to the connection between the well bore and the reservoir reduces the effectiveness of perforation and stimulation.

In-field Gas Gathering

The gas produced by a CBM well is often at low pressure. This is a key area where companies have used innovative technology to lower costs. As the gas is low in pressure, there is no need to use high pressure steel pipelines. Instead, plastic pipes can be used to transport the gas to the compressor. Once compressed, the gas enters a high pressure pipeline before being sent to market.

Monetising CBM Reserves

Due to its unconventional nature, CBM producers initially had difficulties persuading gas purchasers to enter into contracts. This was mainly achieved by undercutting existing suppliers by offering discounted gas prices. As CBM became more established, companies were able to reduce the discount while still remaining competitive with conventional sources. By adopting this strategy CBM has managed to develop significant market share and in some regions it is seen to be a significant threat to conventional gas players.

Importance of Reserves Certification

It is not uncommon for Governments and CBM companies to state reserve potential for a region or project to be several tcf. When first considered, these numbers can seem very ambitious, particularly for an unconventional resource. When estimating the potential resource for a country or project four factors need to be considered:

1. How much coal is there?
2. How much coal has CBM potential?
3. What is the gas content of the CBM coal?
4. How much of the gas can be produced economically?

Generally, those involved are optimistic on all four fronts and this leads to 3P reserve estimates of several tcf. A good rule of thumb is to take a 3P reserve estimate and apply a recovery factor of 25%. By applying this factor, a more realistic estimate of recoverable reserves can be obtained.

One of the most important trends to occur in the past few years has been certification of reserves by independent consultants. All of the major CBM projects have taken this approach and it is likely that many of the smaller projects will also follow this route in the future.

Certification removes one of the major question marks that previously blighted CBM developments: "How much gas is really there?" Certification makes it easier to market the gas as it provides the necessary assurance to gas purchasers. It also provides the equity market with a means to benchmark CBM companies against conventional oil and gas companies. This makes CBM companies less "niche" and more "mainstream".

Gas Marketing

Chemically CBM is identical to any other source of gas. Therefore, once it has been dried and compressed it can be sold into any market. Often, the main customers are base load power generators. This is because CBM supply cannot be switched on and off depending on demand, as wells that are shut-in start to water again. Another factor is the relatively long lead times required for production to be increased to meet new contracts. Lead times of two years are typical to allow for wells to be drilled and to allow sufficient time for dewatering and subsequent commercial production of gas.

However, as with conventional sources of gas, should the project be remote from the gas market then the development might not proceed. In such cases some companies have adopted the so called "wellhead to wires" strategy. In such a project the operator develops the upstream, pipeline and also installs and runs the associated power plant. The electricity generated is then sold directly into the national electricity market. Such projects provide higher revenue streams than upstream only projects. It is also attractive to power purchasers as it reduces their risk profile by negating their exposure to upstream uncertainties. An example of such a project is Queensland Gas' development of the Chinchilla field to supply a 57 MW power station.

Remaining CBM Issues

As CBM becomes more widespread (particularly in the USA and Australia), a number of issues are impacting the industry. The issues include: water disposal, land access, licensing and methane loss to atmosphere. These issues are likely to be overcome and should not affect the long term viability of the industry.

Water Disposal

A new CBM can produce large volumes of water during its early stage of production. The volume decreases over time. Water disposal is an issue as it is often very saline and cannot be dumped into surface water supplies or be used for irrigation. Often the water is re-injected into subsurface rock formations, but this has led to concerns about contamination of the water table. In hot countries such as Australia, the water is put into evaporation ponds. In cold countries, the water is allowed to freeze and the salts are collected allowing surface disposal of the clean water.

Land Access

CBM projects cover large areas of land. In some cases this land is already used for other uses e.g. agriculture. CBM producers need access to drill hundreds of wells and this can cause conflict with land owners. There have been several cases of land owners seeking injunctions to prevent access resulting in projects being delayed or even cancelled. Horizontal drilling can be used to mitigate against land access issues.

Licensing

The unconventional nature of CBM has caused problems when granting production licences. There has been confusion regarding what resource the licence covers, gas only or gas and coal. In most cases CBM producers are only interested in the gas resource, but the ambiguity has resulted in amendments to licensing rules in some countries e.g. Australia.

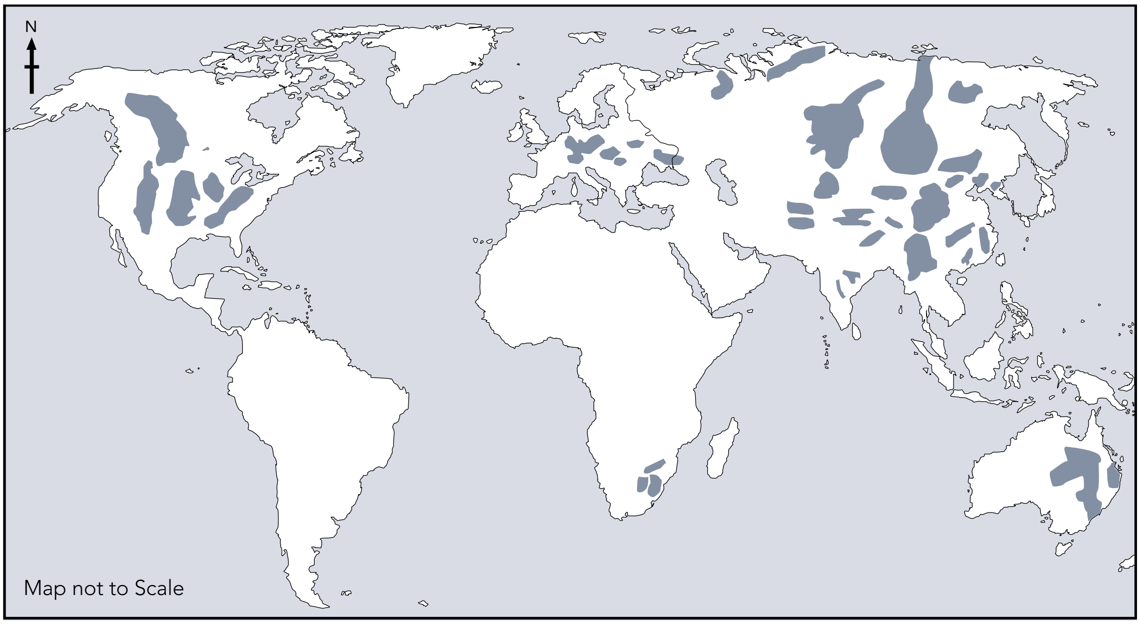
Methane Loss to Atmosphere

Methane heats the atmosphere twenty one times more than carbon dioxide, making it a more harmful emission. Conventional coal mining operations release large volumes of methane into the atmosphere. CBM and CMM are seen as ways to reduce methane emissions and this bolsters their green credentials.

Key CBM Markets

The success of CBM in the United States and Australia has prompted other countries to examine their CBM potential. Growing acceptance by the gas market has seen the perception of CBM shift from being unconventional to mainstream.

Exhibit 10: Identified CBM Basins

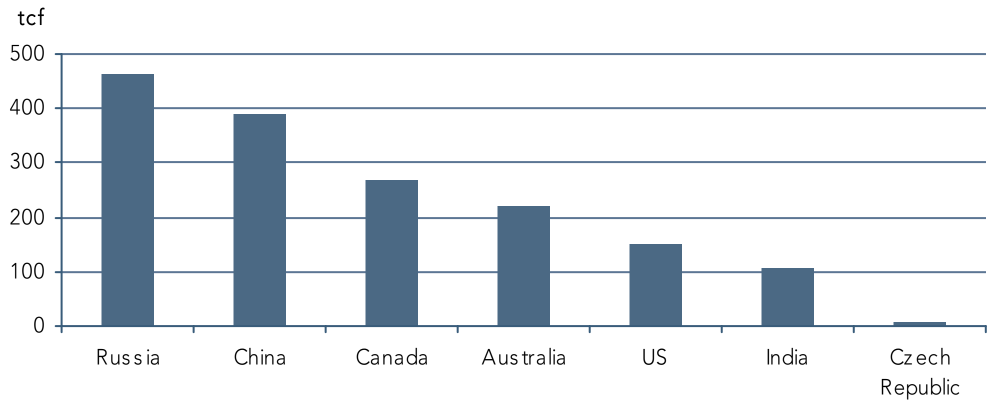


Source: Various

Existing Markets

Only a handful of countries have examined their coal reserves to determine its CBM potential. Following the success of the industry in the United States and Australia, other countries are now developing plans to initiate CBM production.

Exhibit 11: CBM Reserves (Gas in Place) by country

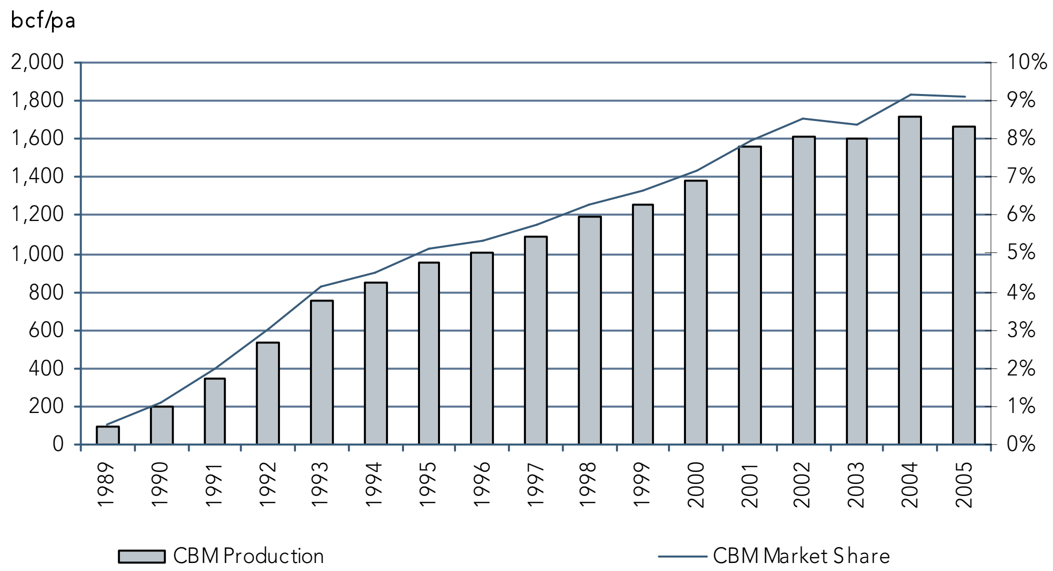


Source: Various

United States

The United States has the most mature CBM market with over twenty years of production and it now accounts for approximately 10% of domestic gas production. The development of CBM was helped by the introduction of tax credits for unconventional resources. These tax credits aimed to improve the competitiveness of resources versus conventional projects. The value of this credit started at around US$0.50/mcf in 1980, but due to inflation reached US$1.10/mcf by 2002. This tax credit allowed producers to reduce their tax liability for all wells drilled between 1980 and 1993. The credit effectively provided the upstream industry with an incentive to actively pursue CBM gas projects, spurred additional drilling activity and further enhanced the economic viability of marginal resources.

Exhibit 12: United States CBM Production History



Source: EIA

The development of CBM started in the Black Warrior Basin of Alabama in the 1970s. By the mid-1980s, the technology and economics of the play had been proven and there was an active drilling programme in the basin. CBM production from the Black Warrior Basin peaked in 1998 at 113bcfpa and has remained stable around 109bcfpa since that time. The Basin has recovered approximately 1.5tcf to date from a total of 6,000 wells.

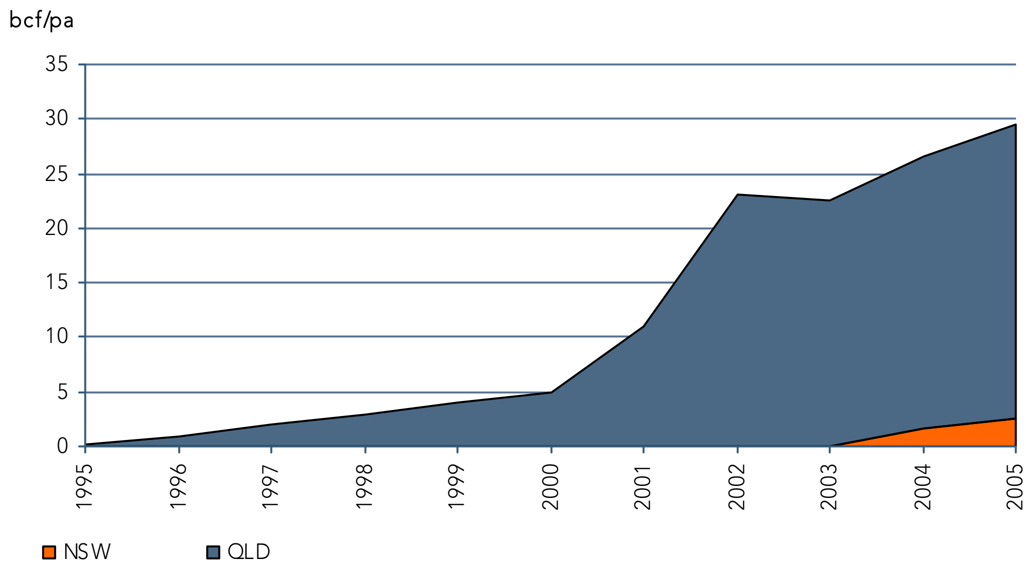
The San Juan Basin was the next significant CBM play to emerge. Drilling activity began in earnest during the mid 1980s. Wells in the San Juan proved to be more productive than those found in the Black Warrior Basin, with average cumulative recoveries of around 4bcf as opposed to recoveries of 0.4bcf in the Warrior. Since the mid-1980s, the San Juan Basin has become the most prolific CBM basin in the world. Production from the basin peaked in 1999 at around 895bcfpa, with cumulative recovery to date estimated at 10.6tcf. There are around 4,000 active CBM wells in the basin and production appears to be relatively flat at around 665bcfpa.

The late 1990s saw an explosion of CBM development in the United States. Pilot projects appeared in coal basins across the country, including the Arkoma, Cherokee, Green River, Forest City, Piceance, Powder River and the Raton basins. Some of these regions were deemed to be uneconomic as the coal was of lower rank, but companies have now realised that the sheer volume of coal present and the shallow depths of wells (typically between 180m – 400m) more than compensates for lower gas content. Since 2000, Powder River CBM has been one of the most active plays in the US market. Currently, the Fort Union coals are producing around 465bcfpa from over 11,000 producing wells. The federal government estimates that there will eventually be 27,000 CBM wells drilled in the basin.

Australia

Australia has been producing CBM for over fifteen years. Despite the limited gas market opportunities, CBM now accounts for 30% of gas supplied in Queensland (QLD). The growth of CBM has caused the Papua New Guinea to Australia gas pipeline project to be delayed for a number of years despite being able to supply much greater volumes at a similar price. New South Wales (NSW) is a key gas market due to high population density and the absence of any local conventional gas resource. CBM developments have recently been developed there and they are likely to replace some of the gas supplied by the Cooper Basin region which is now in decline.

Exhibit 13: Australian CBM Production History



Source: Queensland Government and Sydney Gas

The first attempts to develop CBM projects began in the late 1980s until the early 1990s. These first efforts copied techniques that were successful in the United States. The wells targeted shallow coal seams with moderate to high permeability. Over this period, over US$130mn was spent in Australia. However, these endeavours failed to produce gas at commercial rates in most cases. Consequently, major companies such as Conoco withdrew from the industry and CBM was considered to be an expensive white elephant to potential gas customers.

Despite these initial set-backs, a number of companies persevered with CBM through the 1990s. They re-examined the techniques used and the coals targeted and realised that things would need to change if the success observed in the US was to be replicated in Australia. Those involved were small independent exploration and production companies and so they had to take a low cost approach to solve the problems. The resultant technology and techniques that were found to be successful varied considerably between companies and tended to be bespoke in construction depending upon the properties of each project.

CMM is actively produced in Australia, which ranks sixth globally in CMM emissions (18.4mn metric tons CO_2 equivalent). Mining companies such as BHP Billiton and Envirogen use CMM gas for on-site electricity generation. The Australian Greenhouse Office provides funding to CMM projects with an aim of reducing Australia's greenhouse gas emissions. With the exception of the United States, Australia has the most commercially advanced CMM and CBM industry.

Canada

Western Canada has vast coal resources, but the first pilot CBM project did not start until 2000 with first commercial production in 2003 from the Horseshoe Canyon in central Alberta. The industry is only at the early stages of development, with some of the largest plays still only in the appraisal phase, so evaluating reserves potential and how production might evolve is difficult. Gas sales are estimated to be 665bcfpa by 2006 (2% of domestic production).

CBM exploration began in 1977 with drilling in the Coleman-Canmore corridor of the Southern Alberta Foothills. There were several sporadic and largely unsuccessful attempts at exploration over the next 20 years by numerous companies. These companies did not realise that the Canadian CBM plays required different development solutions to what was successful in the United States. However, some of the US experiences are definitely helping developers avoid problems in Western Canada.

Due to declining conventional production, many of the most successful CBM developments in Canada to date have also benefited from being located in easily accessible areas with plenty of spare capacity in existing infrastructure. The Horseshoe Canyon formation in central southern Alberta has seen the largest early development focus and commercial successes, largely due to negligible dewatering requirements.

The CBM resource potential of the Mannville Group in southwest Canada is considered to be the most significant with ultimate reserves estimated between 140tcf and 230tcf. A number of pilot projects have been conducted in Alberta and British Columbia and companies have started to commit significant capital to developments since the end of 2003. Further CBM potential exists and is being tested for commerciality in the Elk Valley and on Vancouver Island in southern British Columbia. Beyond the few areas that have seen commercial production to date, it is hard to predict which plays will prove to be successful. The opportunities are such that a rapid increase in CBM production in Western Canada is almost certain to occur over the next ten years.

China

China is the largest producer and consumer of coal. China's energy needs are met primarily by coal; it consumes virtually all of the coal it produces. It is also the largest emitter (approximately 72 million metric tons of CO_2 equivalents from coal mining activities) of coal mine methane. China's demand for energy has seen its reliance on imports increase in recent years. China is developing LNG and other gas infrastructure as it makes efforts to become less reliant on coal and to reduce pollution. Gas accounts for 3% of energy production and the Government wants to increase this to 9% by 2010.

CBM exploration started in the 1990s and over 30 areas have been tested so far. Petrochina had unsuccessfully spent 11 years trying to develop CBM production, but failed due to poor exploration results and lack of technology. As a result, the Government opened up the sector to participation by foreign companies. There are several with developments under construction e.g. Green Dragon, China United and Fortune Oil. Usually, domestic gas prices are set by the Government, but this is not the case for CBM. As a result, CBM receives preferential treatment over conventional gas supply.

As part of the 11th Five Year plan (covering the period 2006 to 2010), China plans to spend US$375mn to build two pipelines with a total length of 1,390 km for coal-bed gas transmission. The first pipeline, linking Qinshui County of North China's Shanxi Province to Boai County of Henan Province, will be connected to the pipeline pumping natural gas from energy-rich West China to East China. The second pipeline will transmit coal-bed gas from Songzao of southwestern Chongqing. Each pipeline is designed to have an annual gas transmission capacity of approximately 30bcf to 35bcf.

In the Shanxi region, an international consortium of companies (including Sinopec) is spending $1.14 billion over the next five years to develop CBM to supply 189 MW of power generation. China's first commercial production from the Panhe CBM project located in Shanxi Province started in November 2005. Production from the Shanxi region is expected to reach approximately 175 bcfpa by 2010.

Future Markets

In principle, any country with coal reserves (with the characteristics described previously) has the potential to develop CBM projects. However, most countries have limited awareness of this resource and have not tried to do so.

India

India has high demand for gas, but possesses limited gas reserves. It has tried for several years to secure LNG contracts, but has been unsuccessful in doing so. Having seen the success of CBM in the United States it is now seeking to develop its own CBM resources. The Government first started marketing CBM in May 2001 with the release of the first CBM licensing round. The second round opened in May 2003 with nine blocks on offer. In 2006, the Government awarded ten CBM blocks having received 54 offers from both domestic (e.g. ONGC Videsh, GAIL and IOC) and international companies (e.g. BP, CDX Gas and Arrow Energy). ONGC has stated that it is expected that first commercial production from the Jharia CBM block will begin in June 2007. The Government is targeting annual production of approximately 3tcf by 2010.

India's atmospheric CMM releases will grow as its coal production increases over time and as deeper, gassier seams are exploited. CMM has the potential to make a significant impact on the country's energy supply needs. The United Nations Development Programme is funding a Global Environment Facility project at the Moonidih and Sudamdih Mines to recover and use CMM for power generation and as vehicle fuel. The US$18mn project, co-funded by UNIDO and the government of India, seeks to demonstrate technology for producing methane in advance of and during the mining process. The recovered methane will be used to generate electricity and as a fuel for compressed natural gas (CNG) in mine trucks.

Russia

Russia has the largest coal reserves globally and is one of the biggest coal producers. The largest and most important coal-producing area is the Kuznetsk Basin. The Kuznetsk Basin is located in the south-central part of the country and has coal reserves estimated to be in the order of 14.5bn tonnes. About one-third of the coal produced in Russia comes from this region.

Russia is currently the world's fourth largest emitter of CMM but these emissions are expected to decrease over time. CMM emission abatement potential at Russian mines directly depends on the efficiency of degasification systems, and upon mining, geological and reservoir conditions. While Russian mines and mining associations welcome developments leading to the reduction of methane content of mined coal seams, they often lack institutional and technical support to initiate CMM abatement projects.

Gazprom has stated its plan to develop CBM in the Kuznetsk Basin. This area has an estimated 460tcf (gas in place) of CBM resource to a depth of 1,800m. The greater depth used to determine the reserve estimate would suggest that this figure is a very optimistic estimate for the resource. Gazprom are currently coming to the end of a three year pilot project and are aiming to have first commercial production in 2007.

Project Economics

Since companies involved in CBM tend to be small with limited resources, it is imperative that they are able to develop fields in a cost effective way. The nature of developments (initially capital intensive drilling programme followed by long lead times before commercial production rates) means that companies are unable to generate positive cash flow for a number of years.

During the pilot project a company will determine the economic viability of a site. The project economics are determined by a number of factors:

1. Well flow rates
2. Well spacing
3. Cost of drilling and development
4. Development costs
5. Ability to dispose of water cheaply
6. Good land access
7. Access to market

Wells need to be able to produce gas at a rate which is able to supply gas contracts. The coal seams need to have either high gas content with reasonable permeability or low gas content with high permeability. Flow rates of 500mcfd - 1,000mcfd following dewatering are typical, but higher flow rates in certain regions have also been experienced.

The characteristics of the coal will also determine the spacing between the wells. The well spacing will be determined during the pilot project and will be optimised to ensure the greatest volume of gas can be reached. If the permeability of the coal is too low it is possible that it may not be cost effective to produce gas as the well density would have to be higher. In the San Juan Basin wells are drilled every 160acres - 300acres, but in the Powder River Basin it can be as high as 80acres.

Due to the number of wells required for a CBM project, it is essential for the drilling costs to be as low as possible. Projects can require hundreds of wells and drilling accounts for the majority of the capital expenditure. Costs can range from US$35,000 – US$300,000, but some operators have quoted US$1mn. However, these very high cost vertical wells are exceptionally expensive. Development costs are usually dictated by the length of the high pressure pipeline. Typically such pipelines cost US$1mn/km.

The disposal of water can be a significant issue for a development. Produced water is often very saline and cannot be easily disposed of at the surface. Cleaning up water using membrane technology is very expensive and re-injection can also be costly. Therefore, companies need to ensure they are able to identify a method of disposal before large volumes of water are produced.

Land access is becoming a major issue where there is a conflict around land use. Producers may need to pay land owners for access in order to prevent future litigation. Alternatively, where access is an issue, horizontal drilling can reduce the need for access, but these wells are technically more difficult to drill in addition to being more expensive.

Producers will need to identify a market for the gas. Should a project be remote from a market or from infrastructure, then a project may require the construction of a high pressure pipeline. Such pipelines are very expensive to build and the additional tariff to use a third party's pipeline may have a major impact on a project's economics.

Investment Opportunities

CBM is an attractive industry for upstream companies to be involved in and a number of opportunities exist for those wishing to invest in the sector.

IPO & Capital Raising

Companies tend to have limited capital to fund developments and therefore, some have opted to undertake an IPO following successful pilot projects in order to generate the capital required to fund the next phase of development e.g. CH4 in Australia. In many examples, the IPO has been oversubscribed due to the level of interest in the industry. This has particularly been the case in Australia.

Other companies not wishing to follow the IPO route have instead elected to raise funds by recapitalising the company, by issuing rights or establishing a convertible notes facility.

Mergers & Acquisitions

As an industry matures, mergers and acquisitions play an important role in the growth of companies. In Australia, there have been several mergers and acquisitions in recent years. This is because there are a limited number of players and opportunities resulting in fierce competition.

The merger activity between CBM players has been driven by a need to increase reserves and production e.g. Arrow and CH4. These mergers have also helped reduce some company's exposure as an acquisition target for competitors.

The industry has also seen a number of acquisitions by conventional gas players wanting to gain a position in CBM and to remove potential competitive threats e.g. Santos acquired Tipperary Oil and Gas to gain control of Australia's largest and oldest CBM project Fairview in 2005. Santos also made an offer to acquire Queensland Gas, but this has now been rejected. Queensland Gas stated it was sufficiently confident in its abilities and the market to not need Santos' assistance.

Disposal of Assets

As companies grow they are able to high grade assets in their portfolio. Quite often companies will dispose of non core operations that no longer fit into their strategy. In the United States, there are more deals transferring assets between companies as the market is sufficiently large to support a large number of players. This route may be attractive to upstream companies which do not have the resources or capability to undergo a merger or acquisition.

Glossary

API	American Petroleum Institute
bbl(s)	barrel(s)
bcf	billion cubic feet
bcm	billion cubic metres of gas (1 cubic metre = 35.31 cubic feet)
bn	billion
boe	barrels of oil equivalent (1bbl = 6,000cf of natural gas)
bopd	barrels of oil per day
cfd	standard cubic feet per day
chg	change
CoS	chance of success, or risk factor
EMV	expected monetary value
E&P	Exploration and production
EV	enterprise value
ft	feet
GIIP	gas initially in place
in	inches
IPO	initial public offering
IRR	internal rate of return
lead	potential area where one or more accumulations are currently poorly defined and require more data acquisition and/or evaluation in order to be classified as a prospect
m	metres
MCap	market capitalisation
mcf	thousand cubic feet
mD	milidarcy
mmbbls	million barrels of oil
mmboe	million barrels of oil equivalent
mmcf	million cubic feet
mmcfd	million cubic feet per day
mn	million
NAV	net asset value
NGL	natural gas liquids
NOMAD	nominated advisor
NPV	net present value
OGIP	original gas in place
OOIP	original oil in place
P1	proven reserves (reserves considered to have at least 90% chance of being recovered)
P2	probable reserves (reserves considered to have at least 50% chance of being recovered)
P3	possible reserves (reserves considered to have at least 10% chance of being recovered)
2P	Sum of proven plus probable reserves
3P	Sum of proven plus probable reserves plus possible reserves
Play	recognised prospective trend of potential prospects, but which requires more data acquisition and /or evaluation to define specific leads and prospects
Prospect	potential accumulation that is sufficiently well defined to represent a viable drilling target
psi	pounds per square inch
q-o-q	quarter-on-quarter
SPO	secondary public offering
strip	an arithmetic average of forward prices over a given number of months
t	tonne (1t = 7.33 barrels of crude oil)
t/d	tonnes per day
Upstream	Exploration and production segment of the oil industry
y-o-y	year-on-year
YTD	Year to date

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Coal Bed Methane

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