

COALBED METHANE EXTRACTION AND UTILISATION

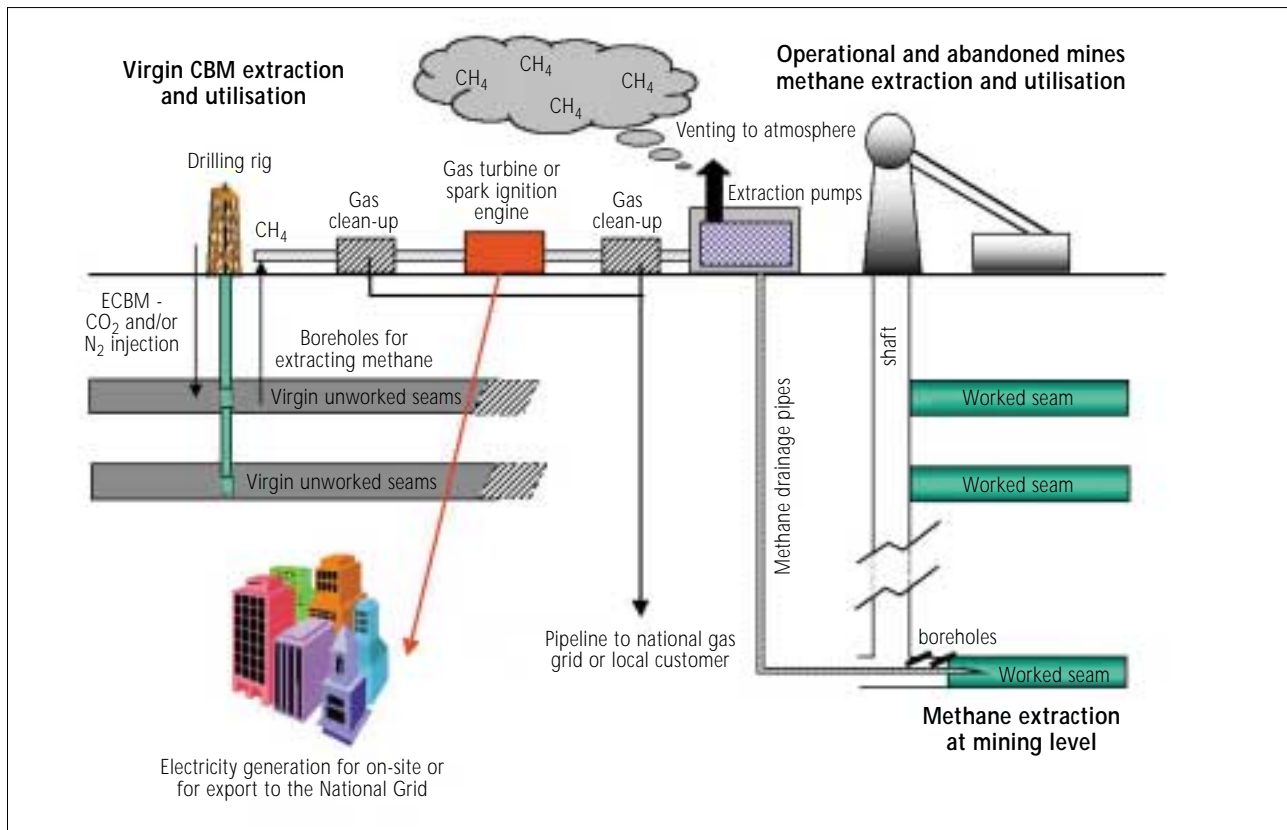


Figure 1. Options for methane extraction and utilisation

INTRODUCTION AND SCOPE

During the process of coalification, plant matter, deposited on the ground, undergoes biological and thermal degradation. Bacteria are responsible for the biodegradation, while thermal degradation results from the increases in temperature and pressure as more layers of plant matter are deposited. The conversion of plant matter to coal produces gases, which are either adsorbed onto the coal or dispersed into pore spaces around the coal seam. The generic term for this gas is coalbed methane (CBM). However, it also contains ethane, carbon dioxide (CO₂), nitrogen (N₂), helium and hydrogen. During the maturation process, large amounts of water are released, resulting in coalbeds that are naturally fractured, low-permeability, water-saturated gas reservoirs.

The majority of gas is in a sorbed state and attached to the coal surface in micropores. Generally the surface area of the coal on which the gas is adsorbed is huge (20-200m² g⁻¹) and saturated CBM reservoirs can easily contain five times the amount of gas contained in conventional gas reservoirs of comparable size, temperature and pressure.

CBM is released in significant quantities when coal is destressed or fractured by mining. Further gas is released throughout the life of the mine, and after the mine has been abandoned. Not only is this an

environmental hazard because methane is one of the main greenhouse gases contributing to global warming, but it is also a potentially important energy resource.

Significant volumes of CBM are exploited worldwide and Figure 1 shows how methane can be recovered in various ways. These include:

- draining, prior to it entering the mine air stream
- collection from abandoned mines
- extraction from 'virgin' coal seams, ie where mining has yet (or is unlikely ever) to take place. This also includes enhanced recovery methods, where CO₂ or N₂ is injected into the coalbed.

For the purposes of this publication, the following acronyms have been used:

- CMM (coal mine methane) – methane extracted from operational mines.
- AMM (abandoned mine methane) – methane extracted from abandoned mines.
- VCBM (virgin CBM) – methane produced from unmined or virgin coal using surface boreholes.
- ECBM (enhanced CBM) – recovery of CBM using CO₂ or N₂ injection.

Other terms are also in use within the industry but definitions vary from country to country.

This brochure focuses on the UK companies, research institutions and universities that have developed expertise in the field of CBM extraction and utilisation. It includes equipment manufacturers, project developers, operators, engineering and consultancy companies and those universities involved with research and development for all aspects of CBM.

SOURCES OF METHANE

CMM

Drainage of methane prior to it entering the mine air stream is standard practice for any operating mine because the methane emissions within the mine have to be maintained below a certain level for safety reasons. More recently, greater emphasis has been placed on utilising this methane as an energy resource to reduce the amount of methane vented to the atmosphere. Currently ~40% of the gas drained in UK mines is used and this could increase to 70% if the proposed new schemes are introduced.

AMM

More recently, it was recognised that exploitation of gas from abandoned mines was an important CBM development. Europe, and the UK in particular, leads the world in AMM production. Much of the future commercial methane production (independent of operational coal mining) in the UK will probably be dominated by the exploitation of gas from abandoned mines. There are currently six abandoned mine gas schemes operational in the UK and more are planned. Figure 2 is an example of one of the AMM sites in the UK.



Figure 2. 5MW_e AMM power plant at Hickleton, UK (courtesy of Octagon Energy Ltd)

VCBM

Most of the world's CBM resource lies in seams unlikely to be mined except in the distant future. Although considerable effort has been expended in exploring and testing VCBM wells, no major commercial schemes have yet been developed outside the USA and Australia. This is a relatively new area of research in the UK.

CBM looks promising in the UK and to date several wells have been drilled in Scotland and Wales, with future prospects in parts of northern England. Although there is some interest in virgin coal seams, indications are that only modest gas flows may be produced in specific areas. ECBM methods, where CO₂ or N₂ gases are injected into the coalbed, have been tried out in the USA and in Canada, but there is now a growing interest in the UK as well.

UK CAPABILITIES

CBM PROJECT OPERATORS

The UK has a long history of CMM exploitation and has seen a rapid growth in the extraction and use of AMM in the past few years. VCBM exploration started in 1992. Interest in CBM in the UK continues to grow as demonstrated by the take up of the Petroleum Exploration and Development Licence (PEDL) areas under the recent ninth round submissions. The success of CMM and AMM projects in a highly competitive energy market has demonstrated to the energy industry and financial markets the potential of small-scale CBM schemes.

A number of UK operators have been successful in raising funds to develop projects. Partnerships between CBM operators and energy suppliers continue to be developed, strengthening the market for the extraction and use of CBM. Operators of AMM projects include **Alkane Energy plc**, **StrataGas plc**, and **Octagon Energy Ltd**. Operators of CMM projects include **Hyder** and **UK Coal Mining**. More details of the existing CBM projects are listed in Table 1.

Table 1. CBM use in the UK (Creedy et al 2001)

| Operator | Site | Use | Output ⁽¹⁾ (MW _e) |
|----------------|------------------------------------|---|--|
| Alkane Energy | Markham, Derbyshire | Delivered by dedicated pipeline (500m) to boilers | 6 |
| Alkane Energy | Steetley, Nottinghamshire | Electrical generation using one 3MW _e spark ignition engine | 3 |
| Alkane Energy | Shirebrook, Derbyshire | Electrical generation using five 1.8MW _e spark ignition engines | 9 |
| Octagon | Silverdale, Staffordshire | Burner tip use and electrical generation (spark ignition engines). Gas supplied using local gas distribution grid | 9 |
| Octagon | Hickleton, South Yorkshire | Electrical generation using four 1.35MW _e spark ignition engines | 5.5 |
| StrataGas | Bentinck, Nottinghamshire | Electrical generation using three 3.5MW _e spark ignition engines | 10 |
| Hyder | Tower colliery, South Wales | Electrical generation for on-site use with six 1.35MW _e spark ignition engines | 8 |
| UK Coal Mining | Harworth colliery, North Yorkshire | Electrical generation using combined cycle, two 4MW _e gas turbines, waste heat boiler and 10MW _e condensing steam turbine | 14 |

Note ⁽¹⁾ equivalent electrical generation

The initial analysis of coal seams for possible VCBM exploitation has indicated that UK coals have a low permeability. This has not deterred some companies and some progress has been made with VCBM. For example **Evergreen Resources UK** is applying its considerable experience gained in the Raton basin in the USA combined with state-of-the-art drilling and completion methods to evaluate the potential. To date (2001), the company has drilled eight wells, three in North Wales, and has completed a five-well pilot scheme near Chester, Cheshire (Figure 3). **Coalbed Methane** has completed four wells in central Scotland and **Enron** has completed one well in south Wales. **GeoMet UK**, another USA-based company, is now examining the potential for VCBM in the UK.



Figure 3. Evergreen Resources (UK) Ltd drilling in Cheshire, UK (courtesy of Wardell Armstrong)

PROJECT DEVELOPERS

A number of UK companies are able to supply a range of services for project development. Those that offer full turnkey services include **Clarke Energy** and **DEUTZ UK**. Clarke Energy was responsible for the development of the Shirebrook Colliery CMM project in 2000 and more recently (2001) has been involved with the development of the Thoresby CMM project, while DEUTZ UK offers capability for all types of engine-based power generation, with speciality in using CBM.

Coastal Oil and Gas, **Coalbed Methane** and **Evergreen Resources UK** have interests in VCBM exploration. Coastal Oil and Gas is currently developing a 50-well VCBM and associated power plant project in south Wales in conjunction with a Japanese partner. Coalbed Methane Ltd was among the first companies to be awarded UK licences for VCBM in 1991 and the company has drilled, stimulated and equipped five wells in the limestone coal formation of the Clackmannan syncline, which could have the most promising CBM potential in the UK. Evergreen Resources UK has exploration licences for more than half a million acres. The company plans to drill and test a multi-well CBM pilot-programme on the Cheshire Basin.

Numerous companies have been involved with the development of AMM and CMM projects. **Alkane Energy** currently has three Green Energy Parks utilising AMM in full production and has future plans to develop over 100 sites. **Edinburgh Oil & Gas** has expertise in the evaluation and operation of abandoned coal mines for commercial production of AMM. It will also be responsible for CBM gas extraction and processing facilities which will supply ~2 million ft³ of gas per day to a 10MW_e power plant to be constructed by Cogen Ltd. **First Energy** is currently constructing a 23MW_e CMM site and operating 30MW_e of embedded gas generators. **Octagon** is one of the largest CBM acreage holders in the UK, with interests in 21 petroleum licence blocks covering 2100km² (in excess of 500,000 acres). Wheldale 10MW_e power plant in South Yorkshire (UK), which is designed to run on AMM, is owned by **Scottish and Southern Energy**. The company is actively looking to develop further CBM-fuelled generation projects in the same region and further afield. **UK Coal Mining** currently operates two CMM sites but aims to increase methane utilisation by 135% before 2005.

UK Gas is the holder of PEDL 014 covering 500km² in south Wales and has identified 17 mine gas projects. Its sister company, UK Methane Limited, is developing the use of new generation, high-capacity fuel cells for the generation of electricity from CBM in conjunction with a Japanese partner. **Warwick Energy** is about to bring on-line a 10MW_e AMM site and owns and operates a further five power generation plant.

Energy Developments (UK) is an operator, owner and developer of CMM projects. Its parent company owns and operates the world's largest coal mine gas generation project which utilises ventilation and CMM gas at Appin Colliery in Australia (Figure 4).



Figure 4. Ducting methane in ventilation air for combustion in gas engines at BHP's Appin Colliery, Australia (courtesy of Wardell Armstrong)

Other project developers include **GeoMet UK**, **Rolls-Royce Power Ventures** and **Renewable Energy Systems**.

EQUIPMENT MANUFACTURERS

For successful utilisation of the extracted CBM, a number of UK companies can provide combustion and drilling equipment and gas turbines.

For example **MAN B&W Diesel** manufactures spark ignition gas and dual-fuel engines. **Hamworthy Combustion Engineering** manufactures equipment suitable for burning CBM usually in combination with fuel oil or natural gas in large water-tube boilers or packaged fire-tube boilers. **ALSTOM Power UK** designs and manufactures small industrial gas turbines, supporting the power generation, combined heat and power (CHP) and oil and gas industries. The company offers turbines in the 4-13MW_e range. **Peter Botherhood** supplies a range of gas compressors for gas turbine fuel compression and other equipment relating to waste-heat applications. Specialist drilling equipment can be designed and manufactured by **EDECO Petroleum Services**.

ENGINEERING, CONSULTANCY AND RELATED SERVICES

The UK has a range of engineering and consultancy capabilities. For the purposes of this publication, the various services have been spilt into:

- **Drilling services.** This includes companies that can provide drilling equipment, drilling services (logging and coring) and advice relating to drilling.
- **Geological services.** This includes the full range of activities relating to analysis of coal, geological surveys, analysis of resources and reserves, and site selection.
- **Laboratory analytical services.**
- **General consultancy and engineering.** This covers a broad range of advice on planning permission, environmental impact assessments, feasibility studies, construction, design of equipment or projects and project planning.

Drilling Services

The gas production potential of CBM wells depends on gas transmissibility within the seams; accurate drilling and *in situ* testing is therefore essential for site selection. 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 the ability to locate guidance sensors directly behind the drill bit, have resulted in the development of a new generation of guided drill equipment capable of providing greater accuracy, increased drilling speeds and cleaner hole completions.

The UK has a number of companies that have experience in drilling in coal seams. **Evergreen Resources UK** has a drilling rig which will have the capability to both drill and complete 3500ft wells. **UK Gas** has been developing innovative drilling and completion techniques utilising a multi-drive directional drilling rig. The technique when perfected will allow numerous holes to be drilled at either 30° or 45° from one surface entry point, thereby minimising planning permissions and pipeline costs.

EDECO Petroleum Services, PR Marriott Drilling and Schlumberger Oilfield Services are suppliers of drilling services. In most cases the companies can provide services which include complete drilling (eg directional or horizontal), coring, logging and borehole casing. A number of companies are able to provide back-up services. For example, **Harworth Mining Consultancy, Stratagas and WS Atkins** can design and manage drilling contracts. **International Mining Consultants** has recent experience in the design and management of onshore drilling projects at all scales up to ~1km in depth and **Celtic Energy** provides drilling advice to CBM developers.

Once drilling has been completed, **Pipeline Services** has the capabilities to install pipes for gas extraction.

Geological Services

The composition and character of coal is determined by the nature of the original organic and inorganic material, as well as by the degree of coalification. It is therefore important to have an understanding of the chemical and physical properties of the coal. Geologically the most desirable CBM sites will have coal seams that are saturated with, or without, free gas and have moderate permeability. Permeability is the measure of the ability of a rock to conduct fluid. The conventional unit of permeability is the millidarcy (md).

Factors that influence the selection of well sites include geology, gas content, environmental impact, water disposal options, access and market opportunities. **ACA Howe International, British Geological Survey**

(**BGS**), **Harworth Mining Consultancy, Stratagas, Wardell Armstrong** and **WS Atkins** are experienced geological consultancies that can provide a range of geological services. These services can include:

- coal analysis and geology
- stratigraphic and structural analysis
- site characterisation and exploration
- seismic data interpretation
- borehole analysis studies
- reservoir and resource characterisation
- geological mapping
- geophysical surveying
- hydrogeological studies.

Geophysical downhole measurements using electric wireline logging services can be provided by **Reeves Wireline Services** and **ACA Howe**.

Computer modelling of gas reserves has become a powerful tool to study the behaviour of CBM and production-well bore performance. There are about 40 simulators listed in literature that are based on principles of gas flow in porous permeable media. These also include simulators that are used to model the production of methane with time. Some UK universities and consultancies have developed modelling expertise.

For example, research at the **University of Cardiff** has involved modelling the complex relations between fracture openness and fracture fill.

Nottingham University has developed a model for fluid-flow rock mechanics that is coupled to a CBM/CMM model. The TH Huxley School of Environment, Earth Sciences and Engineering at the **Imperial College of Science Technology and Medicine (ICSTM)** has been involved in CBM research and methane simulator development since 1979, investigating the geotechnical and gas flow behaviour of mined and unmined coal seams as natural gas reservoirs.

ACA Howe has the capabilities to digitally compile data for three-dimensional (3-D) modelling, graphical presentation and reporting. **BGS** has a range of information technology expertise, including geographical information systems (GIS) applications and 3-D modelling of subsurface reserves. **Harworth Mining Consultancy** also has a comprehensive deposit modelling capability and **Wardell Armstrong** has an abandoned mine gas reservoir model (see Figure 5).

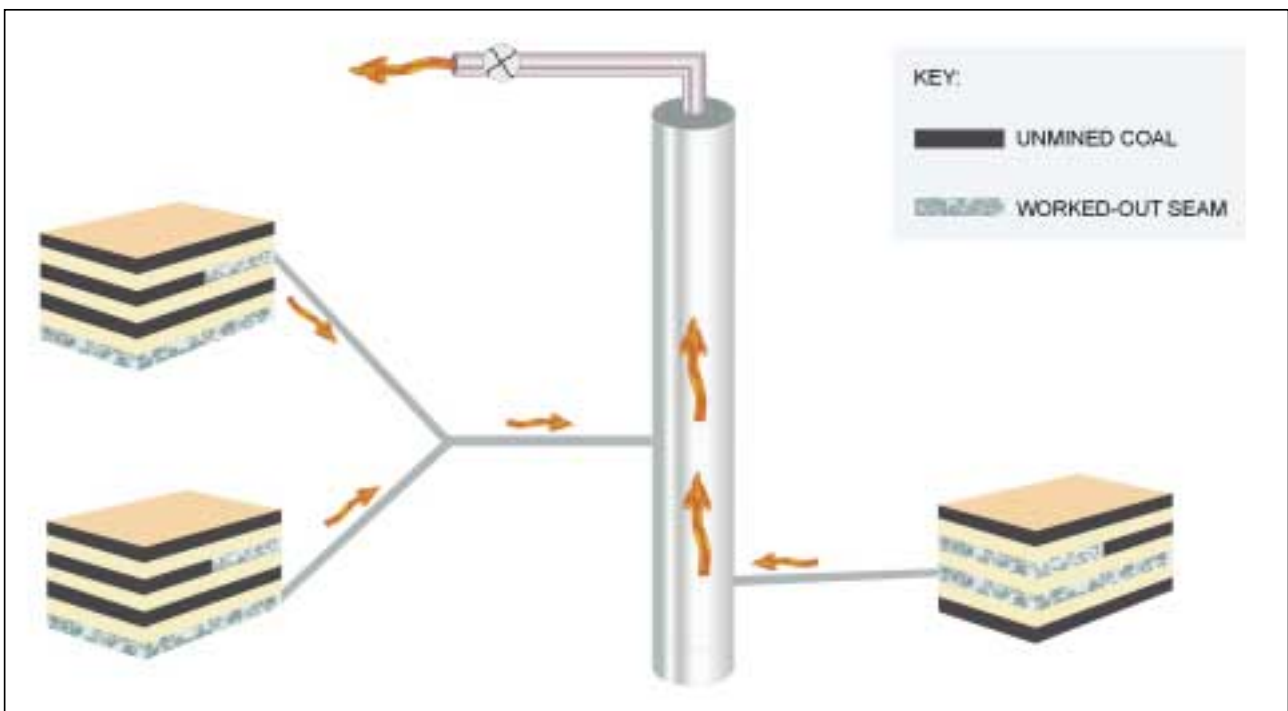


Figure 5. Abandoned mine gas reservoir model (courtesy of Wardell Armstrong)

DIRECTORY

EQUIPMENT MANUFACTURERS

ALSTOM Power UK Limited

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ALSTOM Power UK designs, manufactures and services small industrial gas turbines, supporting the power generation, CHP and oil and gas industries. The company currently offers a range of industrial gas turbines from 4MW_e to 13MW_e.

Two ALSTOM TB5400 gas turbines (model no longer manufactured) have been installed at Harworth Colliery, near Doncaster (UK). These turbines operate on CMM and have been in constant use since their installation in early 1993. Operation of the turbines is contracted to Elyo UK Ltd, whilst the maintenance of the turbines, which has been routine over this period, is contracted to ALSTOM. The gas turbines produce around 3.5MW_e each and the exhaust heat from the turbines, with the addition of some supplementary firing, is used to raise steam to drive a steam turbine, which adds a further 5MW_e output. The combined-cycle plant is the main source of power for the colliery and nominally produces around 12MW_e, although it has the capacity to produce up to 18MW_e if required. The colliery can thus be self-sufficient, generating the power it needs from the CMM it would otherwise vent to the atmosphere.



Figure 6. Inside ALSTOM's Lincoln (UK) manufacturing facilities (courtesy of ALSTOM Power UK Ltd)

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Hamworthy Combustion Engineering manufactures equipment suitable for burning CBM, usually in combination with fuel oil or natural gas, in large water-tube boilers or packaged fire-tube boilers. Typically, Hamworthy supplies complete systems, including burners, ignition, flame proving, burner management systems, combustion controls, fuel valves and pipe-work, all in accordance with health and safety regulations.

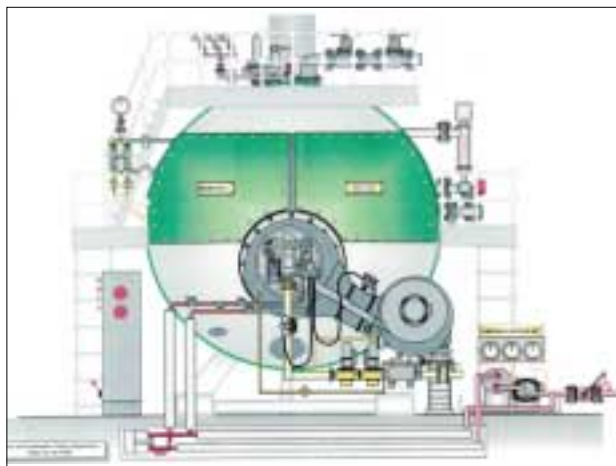


Figure 7. Triple-fuel burner fitted to 30,000PPH Maxecon boiler (courtesy of Hamworthy Combustion Engineering Ltd)

MAN B&W Diesel Limited, Ruston

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MAN B&W Diesel, Ruston manufactures spark-ignited gas and dual-fuel engines, which are capable of running on a range of gases. The engines are available in the 810-3550kWb power range and operate at speeds of 720-1000r min⁻¹ for power generation and mechanical drives applications.



Figure 8. Spark-ignited gas engine (courtesy of MAN B&W Diesel Ltd)

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Peter Brotherhood supplies a number of products for use in the energy conversion of coal seam gas. Its range of gas compressors and compressor packages is applied to gas turbine fuel compression. With a wide and flexible range of multi-stage condensing, pass-out and back pressure steam turbine generators, almost any fired boiler or waste-heat application can be addressed. These are the products of the Process and Energy Division of the company, which is also equipped to provide turnkey solutions based on the products and technology.

Providing more direct conversion of gas into useable energy is the speciality of another division of the company, Brotherhood Aircogen. Designing and manufacturing both packaged and turnkey gas engine CHP packages, Aircogen brings a number of unique technologies to the market, covering a wide range of CHP applications.

DEVELOPERS

Alkane Energy plc

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Alkane Energy is a market leader in the commercial extraction of methane gas from abandoned coal mines, using unique technology to pump the gas from underground seams.

Alkane Energy extracts gas from abandoned coal mines for direct supply to local consumers or for on-site power generation. The company currently has three Green Energy Parks in full production, is constructing several new sites, and has many more at the predevelopment stage. Future plans to develop over 100 sites could prevent as much as 20 million tonnes of CO₂ per annum from entering the atmosphere.

Alkane Energy possesses unique vacuum-pump technology for the extraction of AMM.

Alkane Energy would be interested in joint ventures or partnerships to expand internationally.

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Clarke Energy is a foremost turnkey supplier of CHP and gas-powered generation schemes. Within the UK, the company has recently (2000) developed the Shirebrook Colliery Mine Gas Project (UK), where it installed five 2MW_e generators, and is currently (2001) developing the Thoresby Colliery Mine Gas Project (UK), where a 2.2MW_e generator is being installed.



Figure 9. Shirebrook CMM gas project (courtesy of Clarke Energy Ltd)

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Coastal Oil and Gas is the holder of PEDL 100 covering 230km² on the southern edge of the South Wales Coalfield. The company has identified substantial mine gas and distressed CBM reserves in the strata surrounding the old Morfa Colliery workings, which underlie Corus' Port Talbot steel plant and the nearby British Oxygen plant, both of which have very high energy usage. The company has a further 50-well VCBM development and associated power plant planned for the area in conjunction with a Japanese partner.

Coalbed Methane Limited

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Coalbed Methane Ltd (CBML) is a developer of CBM projects.

CBML was among the first companies to be awarded UK licences for VCBM in 1991 and the company has drilled, stimulated and equipped five wells in the limestone coal formation of the Clackmannan syncline, which could have the most promising CBM potential in the UK.

Licences currently held by CBML (2001) cover 1148km². Well sites have been purchased and pipeline agreements made with local landowners. Agreements are in place with the UK Coal Authority and Scottish Coal who operate the only remaining Scottish underground coal mine. Planning consents for the wells were granted within a few weeks of first application.

DEUTZ UK Limited

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Deutz Energy is DEUTZ UK's power systems division providing effective solutions for all energy requirements. The company offers a complete turnkey project capability for all types of engine-based power generation and CHP applications and is particularly expert in the supply of power plant for the utilisation of CBM. DEUTZ UK Ltd is a wholly owned subsidiary of DEUTZ AG, an independent engine manufacturer.

Energy Developments (UK) Limited

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Energy Developments (UK) is an operator, owner and developer of, and arranges finance for, coalmine projects. Its parent company owns and operates the world's largest coal mine gas generation project (the 98MW Appin/Tower mines project in New South Wales, Australia, which is fired with ventilation and CMM gas).

Edinburgh Oil & Gas plc

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Edinburgh Oil & Gas owns and operates four UK onshore licences with CBM development potential. On one of these licences, PEDL057, gas extraction and processing facilities are being installed in the fourth quarter of 2001 and approximately 2 million ft³ of gas per day will be pipelined to a 10MW_e power plant that will be constructed by Cogen Ltd. The company's expertise lies in the evaluation and operation of abandoned coal mines for commercial production of AMM.

Evergreen Resources UK Limited

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Evergreen Resources UK (ERUK) is a developer of CBM projects. ERUK has exploration licences for more than half a million acres. The company plans to drill and test a multi-well CBM pilot-programme on the Cheshire Basin (UK). The drilling rig will have the capability to both drill and complete 3500ft wells. ERUK also plans to target several wells to test the potential of what is known as 'gob' gas (AMM). Gob gas is essentially methane gas that has been collected in abandoned underground coal mines. ERUK plans to demonstrate the market for its future gas production by supplying AMM gas to local power generation utilities this year (2001).

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First Energy specialises in the design, manufacture, installation, operation and maintenance of natural or mines-gas driven embedded generating plant. The company is currently constructing a 23MW_e site and operating 30MW_e of embedded gas generators.

First Energy has a production facility in Hereford where it fabricates and assembles generating systems and components for its maintenance programmes. The key personnel at First Energy have been together for over ten years.

GeoMet UK Limited

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GeoMet UK is a developer of CBM projects.

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Octagon Energy is an independent power generation company that develops CBM projects. All efforts are made to ensure that CBM is utilised in a safe and environmentally sensitive way. The company is one of the largest CBM acreage holders in the UK, with interests in 21 petroleum licence blocks covering 2100km² (in excess of 500,000 acres). These interests are located primarily in areas of the main UK coal fields (south Wales, South Yorkshire, Nottinghamshire, around Warrington and in the Solway Firth area).

Backed by a team of experienced directors and an expert group of technical consultants, Octagon is actively involved in a major exploration programme assessing reserves on all of its hydrocarbon licences.



Figure 10. Silverdale gas compression station at Stoke, UK (courtesy of Octagon Energy Ltd)

Renewable Power Systems

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Renewable Power Systems is a developer, designer and project manager of gas-utilisation projects.

Rolls-Royce Power Ventures Limited

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Rolls-Royce Power Ventures is a major international power developer specialising in developing plant in the 5-150MW_e range.

Scottish and Southern Energy plc

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Scottish and Southern Energy is a vertically integrated utility with electricity generation, transmission, distribution and supply assets. The company currently has about four million electricity and one million gas customers and in 1999/2000 traded 15% of the UK's electricity. By 2002, it will generate over 7000MW_e with 85% of the portfolio having an efficiency of 50% or more.

Scottish and Southern Energy is owner of the Wheldale 10MW_e power plant in South Yorkshire (UK), which is designed to run on AMM. The company is actively looking to develop further CBM-fuelled generation projects in the same region and further afield.

Scottish and Southern Energy's core competencies cover the utilisation of CBM for the generation of electricity and include:

- **project development** - including commercial development and contracts, management of grid connections, land acquisition, and planning and consents
- **project management** - management of the development, construction, and long-term operation and maintenance phases of a project; Scottish and Southern Energy is also able to draw on key partnerships with equipment providers
- **project funding** - with a strong balance sheet Scottish and Southern Energy is able to invest in projects directly without the need for separate debt-based project finance
- **energy trading** - including the management of export and direct customer sales; Scottish and Southern Energy can also offer risk management strategies including the provision of back-up fuel supplies if required.

UK Coal Mining Limited

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UK Coal Mining owns and operates a small, combined-cycle gas turbine plant at its Harworth Colliery. Fuelled by CMM, but sometimes mixed with natural gas to maintain calorific value, the plant generates 14MW_e from two ALSTOM Tornado gas turbines and a Peter Brotherhood condensing steam turbine. Power output from this highly efficient arrangement is boosted by supplementary firing of the waste-heat recovery boilers. UK Coal Mining installed two reciprocating engines at Thoresby Colliery during 2001 to generate 1MW_e for use on-site. The company has made a commitment under the UK Department of Environment, Food and Rural Affairs (DEFRA) 'Making a Corporate Commitment' campaign to increase its methane utilisation by 135% before 2005; more CMM projects are planned to achieve this environmental objective.



Figure 11. Harworth CHP plant (courtesy of UK Coal Mining Ltd)

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UK Gas is the holder of PEDL 014 covering 500km² in south Wales. The company has identified 17 mine gas projects and is developing innovative drilling and completion techniques utilising a multi-drive directional drilling rig. The rig, which is powered by two 320kW motors, has a 65-tonne pull-back capacity and develops 15,000ft lb⁻¹ of rotational torque. It is capable of drilling up to 1m-diameter holes in rock. The technique when perfected will allow numerous holes to be drilled at either 30° or 45° from one surface entry point, thereby minimising planning permissions and pipeline costs.

UK Gas's sister company, UK Methane Limited, is developing the use of new-generation, high-capacity fuel cells for the generation of electricity from CBM in conjunction with a Japanese partner.

Warwick Energy Limited

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Warwick Energy is currently bringing on-stream its CBM-fired 10MW_e Bentinck Generating Station.

The Station, which is located in Nottinghamshire, UK, utilises the vent gas from the recently closed Bentinck Colliery. The site equipment consists of a gas processing facility and three gas engine generators designed to operate on both mains gas and CBM.

Following final commissioning, the Station will operate on a 24-hour basis and will utilise 3 million ft³ per day of CBM that would otherwise be vented to atmosphere.

Warwick Energy owns and operates a further five power generation plant and is one of the largest on-shore licence acreage holders within the UK.



Figure 12. Bentinck Generating Station (courtesy of Warwick Energy Ltd)

Workington Gas & Light Limited

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Workington Gas & Light is a very new company, applying for its first PEDL in the forthcoming tenth UK onshore round. At this stage the company is concentrating on mine vent gas (CMM) and may only consider VCBM in the future should it be successful in its first application. Key staff are from the chemical industry, and therefore the company will look more widely at uses of the resources.

ENGINEERING, CONSULTANCY AND RELATED SERVICES

ACA Howe International Limited

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website: www.achowe.co.uk

ACA Howe International has been providing a comprehensive range of geological services to extractive industry clients and related financial institutions since 1961. The company has international expertise in coal and CBM exploration and development, including pioneering work in the UK and a field and desk-based project review in Poland, since early 1990. The company provides services to operators and developers of CBM projects worldwide. Its proven capabilities range from preliminary desk-based research, field investigations and project management to participation in feasibility studies and preparation of independent bankable documents.

ACA Howe International has staff, associates and access to industry specialists with international experience and capabilities in the relevant subjects required for many stages of CBM projects. These specialist subjects include:

- project management, site supervision and staffing
- coal geology, coal geo-technical data compilation and interpretation, petroleum geology and basin analysis, stratigraphic and structural analysis
- site characterisation and exploration including drill-hole targeting and well site selection, wireline core drilling management, well site geology and core logging
- regional geophysical interpretation, geophysical wireline logging and interpretation, seismic data interpretation
- hydrogeology and environmental impact assessment
- organisation of laboratory test-work through specialist UK institutions including coal, gas and water analysis, canister desorption testing, and adsorption isotherm experiments
- desk-top studies, data collation, research and analysis of mining and mine abandonment records
- digital data compilation and analysis, 3-D modelling, database management and design, graphical presentation and reporting
- UK local authority planning applications, negotiation and liaison with local landowners
- coal and gas resource and reserve estimation.

AEA Technology Environment

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Website: www.aeat-env.com

AEA Technology Environment is a large independent consultancy that has a strong clean coal technology consultancy capability. The company has undertaken clean coal technology consultancy throughout the world and provides a full range of environmental consultancy such as strategic environmental advice, programme management, technical consultancy, technology transfer, training services and environmental monitoring. In CBM, AEA Technology is active in evaluating national methane emissions and assessing environmental impacts associated with methane use.

Cadogan Consultants Limited

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For nearly 30 years, Cadogan Consultants has provided independent and impartial professional energy-engineering consultancy services to a wide range of clients in the UK and overseas. The company has professional staff, skilled in various engineering fields, and offers a multi-disciplinary service.

Cadogan Consultants has expertise with a wide range of both conventional and renewable energy conversion technologies. The company has particular experience of both CBM and landfill gas projects. This experience includes projects in the UK (for a National Health Service Trust) and in the north east New Territories of Hong Kong, China. The company has particular skills in the provision of energy centres and CHP plant.

Celtic Energy Limited

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Celtic Energy is a coal mining company that provides drilling advice to CBM developers.

EDECO Petroleum Services Limited

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EDECO Petroleum Services Limited offers a range of quality products and services for the development of CBM resources. The company is a leading supplier of deep-drilling services, and it designs and manufactures specialist drilling equipment.

Farley Engineering Limited

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Farley Engineering is a leading company for the implementation of technology associated with CBM extraction, and the subsequent utilisation of methane.

Farley Engineering provides cost-effective innovative solutions to all CBM applications including feasibility studies, testing, planning, electricity generation and export surveys, the provision of extraction equipment, and plant design of all types ranging from simple extraction testing rigs through to complete power stations.

Farley Engineering is entirely independent and has been associated with all the leading UK CBM and mining companies. In-house experience provides over 25 years of CBM utilisation and that experience extends to methane extracted from working mines (CMM), closed mines (AMM), vents and VCBM wells. Utilisation experience extends beyond the extraction of methane and electricity generation to the installation and operation of gas distribution systems together with all the associated pipework, monitoring and controls necessary for the safe operation of such installations.

Harworth Mining Consultancy Limited

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Harworth Mining Consultancy Limited (HMCL) combines consultancy experience of CBM prospecting and evaluation with the practical operations management expertise of its parent company UK Coal (see above). Through this combination, HMCL offers the services of geological, geotechnical engineering and environmental management staff with recent experience of implementing onshore drilling programmes for coal and hydrocarbons to depths in excess of 1km. These staff have been directly involved with the great majority of exploration boreholes and associated prospecting activity performed in the UK over the last decade for coal and coal-related gas resources. HMCL staff have, during this period, participated in major regional evaluation exercises relating to the UK's CBM resources.

Up-to-date practical experience covers:

- design of drilling programmes for deep coal resources
- management of drilling contracts, core measurement and geotechnical assessment of core samples
- acquisition and interpretation of downhole geophysical logs and hydrogeological assessments
- detection and monitoring of gases and hydrocarbon fluids
- deployment of well control equipment
- preparation of statutory health and safety documentation.

The company maintains comprehensive deposit modelling capability and widely experienced hydrogeological and geotechnical associate support permits the regional impacts of cleat and fracture permeability and hydrostatic pressures to be incorporated in appraisal of CBM resources.

HMCL staff have worked closely with the commercial development efforts of potential CBM operators and are active in the co-operative assessment with them of CBM resources within or adjacent to the extensive coal licence areas of UK Coal.

International Mining Consultants

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International Mining Consultants (IMC) offers a comprehensive range of CBM services covering enhanced stimulation and utilisation, which are firmly based on the expertise of proficient and highly trained staff. The IMC Group of companies together covers a wide range of technical expertise. In particular, capabilities include:

- Mapping and reserve assessment - geologists and geophysicists within IMC have developed and deployed the full range of techniques for coal exploration and CBM evaluation. Relevant approaches include two-dimensional (2-D) and 3-D seismic, vertical seismic profile (VSP), in-seam seismic, and a wide range of geophysical borehole logging techniques.
- Over the past six years, IMC carried out the majority of onshore seismic acquisition in the UK for coal and hydrocarbons, and employs the UK's most experienced seismic processors and interpreters in the field of coalfield exploration. These approaches enable the various types of methane resources to be identified. IMC also has expertise to assess the permeability (rock mass discontinuities) and influence of groundwater on CBM extraction.
- Exploratory and production drilling - IMC staff have recent experience in the design and management of onshore drilling projects at all scales up to ~1km in depth. This experience includes the drilling of in-seam boreholes, using both deviated wells from the surface and rigs situated within mines.
- Energy economics and regulatory approval - IMC staff have a worldwide reputation as consultants in the energy sector. In the UK, geo-technical and engineering personnel are engaged with coal, hydrocarbons and CBM operators in all aspects of the development of both conventional and unconventional power projects. IMC has expertise in determining the viability of CBM projects in terms of economics and the available technology.
- Environmental monitoring including abandonment and restoration - IMC has developed seismic monitoring techniques for directly observing seismicity resulting from mining activity and CBM extraction. IMC has investigated numerous mining-related, geological and environmental hazards associated with the legacy of the coal industry and is fully versed in dealing with the environmental impacts of CBM extraction.
- Scientific research - IMC staff have undertaken extensive research into CBM exploration, evaluation, production, utilisation and environmental impacts. This has been undertaken in the UK and overseas, in all three areas of underground gas recovery including drainage in active mines, recovery from abandoned mines and extraction from unworked *in-situ* coal seams.

Knight Energy Services Limited

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Knight Energy Services is part of the Alfred H Knight Group, which has provided an analytical service to the coal industry for over 100 years. The company offers a range of analytical testing to the CBM industry including:

- Proximate and extended analysis of coal cores and cuttings.
- Volumetric measurement and composition analysis of desorbed gases at reservoir temperature.
- Industry standard gas-adsorption testing to produce Langmuir isotherms. Langmuir isotherms describe the gas holding of a solid at varying pressures. 'Gas holding' used to calculate the ideal methane holding capacity of coal.

PR Marriott Drilling Limited

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PR Marriott Drilling offers drilling services for CBM and natural gas exploration. The company operates a fleet of advanced onshore drilling rigs and ancillary equipment.

The company offers a full drilling and well-control service in the UK to guarantee compliance with the Borehole Sites and Operations Regulations (1995) and the Construction (Design and Management) Regulations (1994). These services are offered to the international CBM and natural gas exploration market. The UK-based operation is supported with an advanced engineering facility.

The company is equipped with a fully zoned Ingersoll Rand TH 75 for shallow CBM drilling operations and larger rigs for deeper onshore drilling and workover operations.

The onshore drilling conducted on behalf of operators in the UK has included directional drilling using downhole motors and advanced steerable technology to target abandoned mine workings to depths of 500m and to target natural gas reservoirs at depths up to 2500m.

The CBM drilling activities have been carried out on mainland UK coalfields in Yorkshire, Nottinghamshire and south Wales and in deep natural gas exploration in Northern Ireland. The list of operators who have engaged the services of PR Marriott Drilling Ltd includes Octagon Energy, Evergreen Resources, Alkane Energy, Brabant Petroleum, Candecca (now Star Energy), Global Marine and Cairn Energy.

The people retained by PR Marriott Drilling are fully experienced in both onshore and offshore hydrocarbon operations and are qualified in terms of health and safety management and wellhead control. A full project management and consultancy service is available for UK and global drilling operations.

Pipeline Services Limited

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Pipeline Services are experts in the installation of pipes for gas extraction and the fabrication of products from polyethylene.

Reeves Wireline Services Limited

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Reeves Wireline Services (Reeves) is a UK company providing electric wireline logging services to the energy sector worldwide, offering a wide range of geophysical downhole measurements and various surface systems in boreholes and wells of varying depth, diameter and trajectory.

Reeves began providing logging services to the coal industries of a number of countries worldwide before expanding into the hydrocarbons sector. This crossover and experience base both in coal and oil and gas has placed Reeves in an ideal position to offer logging services to the CBM industry.



Figure 13. Reeves Wireline operating on-site (courtesy Reeves Wireline Services Ltd)

Schlumberger Oilfield Services Limited

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Schlumberger Oilfield Services has been involved in over 220 CBM projects worldwide, working with over 80 different clients. The company's range of CBM services includes prospect analysis, geologic analysis, field development (planning & supervision), well-testing and hydraulic stimulation (design, implementation and analysis), well-bore maintenance, field optimisation (well spacing, in-fill potential), production analysis, production forecasting and reserve assessment.

Schlumberger Oilfield Services' expertise in the following areas provides CBM solutions tailored to the specific needs of the client:

- Seismic - identification of coal seam continuity and structure.
- Drilling - directional/horizontal, under-balanced, coiled tubing.

- Logging - CBM-based suite.
- Coring - improved side-wall coring, large diameter, pressure core.
- Casing/cement - simple, non-damaging cement, single stage, lightweight.
- Perforating - large diameters, shallow penetration.
- Hydraulic stimulation - additives for dewatering, proppant flow-back control, fluid compatibility, proppant volume.
- Production optimisation - low inlet-pressure compression.

Scientific Analysis Limited

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Scientific Analysis is an independent company specialising in a wide range of accredited analytical services. For example, the company undertakes analysis of bore-hole gases.

StrataGas plc

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StrataGas offers a wide range of consultancy and management services in the field of evaluating, planning, developing and operating CBM. CBM experience includes projects associated with both active (CMM) and abandoned (AMM) coalmines and VCBM. The company acts as lead advisory consultant or turnkey project manager on CBM schemes of any size.

Through its team of experienced personnel, the company provides clients with the means to determine if their CBM prospects have the potential to be successful both technically and commercially. If conditions are favourable, the company takes the client through each step necessary to reach a successful commercial project. The services StrataGas offers relating to CBM include:

- feasibility studies
- evaluation of project potential
- commercial appraisal
- estimation of development costs
- design, planning, development and operation of CBM projects
- design, selection and acquisition of equipment and materials
- business plan development
- project planning and management
- drilling programme management
- design and development of project related environmental systems
- training of administrative, professional and technical personnel.

Stratagas team members have been responsible for the successful planning and carrying out of CBM pilot projects and the successful evaluation, planning, development and operation of a major VCBM project in the USA, which comprised >350 VCBM wells and >250 gob wells. The gob wells were associated with an active coalmine that had very gassy coal seams. Team members have also been responsible for the successful evaluation, development and operation of CMM projects in the UK. The company's team members have evaluated CBM resources in the UK, the USA, India, Mexico, Poland, the Czech Republic, Russia and Ukraine.

Wardell Armstrong

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Wardell Armstrong is the largest wholly-independent UK international mining consultancy. The firm has provided mining and specialist coal-related services since its beginning some 150 years ago. It employs 200 professional staff operating from seven offices in the UK and one office in Hong Kong.

Wardell Armstrong has highly qualified and experienced personnel covering all the principal disciplines involved with the support of CBM exploration, assessment and economic valuation. Apart from the UK, the firm has experience of coalfield areas worldwide – most notably in Poland, Eastern Europe, China, India, North America, South Africa and the Far East. Clients include CBM operators, mining companies, research organisations and agencies, financial institutions, government departments and solicitors.

Wardell Armstrong also has considerable experience of research in the CBM field having undertaken gas-related projects for the UK Government, Health and Safety Executive (HSE), CIRIA (Construction Industry Research and Information Association), International Energy Agency (IEA) Coal Research, the European Union and Safety in Mines Research Advisory Committee (South Africa).

Wardell Armstrong's wide experience of CBM comes from projects involving:

- extraction of gas from virgin coal seams
- extraction of gas from abandoned mines
- drainage and utilisation of gas at working coal mines
- regulating interaction between CBM and coal mining activities
- control of gas in underground coal workings
- measurement and prediction of gas emissions in coal mines
- prevention of surface gas emission risks following colliery closures.

Tasks undertaken have included feasibility studies, gas resource and reserve assessments, geological appraisals, due diligence, engineering design, monitoring, training, problem solving, technology reviews and research.

WS Atkins Consultants Limited

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WS Atkins (WSA) is the largest integrated engineering, environmental and management consultancy in Europe. The company is renowned for providing high-quality consulting engineering and technical support services. WSA's 12,000 employees provide a unique resource base with which to compile and manage multi-disciplinary teams to meet project requirements.

Staff and consultants within WS Atkins Mining are experienced in CBM and CMM recovery technologies. The company's capability covers all project development stages, from target selection and evaluation, through planning and licensing, to engineering and project management.

Relevant services include:

- coalfield geological and structural interpretation
- hydrogeological and geotechnical assessment
- target selection
- reservoir characterisation
- planning and supervision of directional drilling
- methane extraction and control systems
- advice on methane utilisation schemes
- environmental impact assessment
- technical and economic evaluation
- licensing and CBM access agreements
- planning applications
- compliance with HSE regulations
- project engineering and management.

UNIVERSITIES/RESEARCH ESTABLISHMENTS

British Geological Survey

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Website: www.bgs.ac.uk

British Geological Survey (BGS) is the UK national centre for Earth Sciences and forms part of the Natural Environment Research Council (NERC). The BGS operates both in the UK and internationally in all aspects of geoscience, and can offer a wide range of geological, geophysical and hydrogeological solutions applicable to the CBM industry. The BGS is the premier data centre for UK geoscientific information including coal resources. The organisation has expertise in all aspects of the coal extraction technologies and has an enviable portfolio of projects in this field.

Specific CBM expertise includes:

- Borehole analysis, including specialist core logging, geophysical logging and formation evaluation, borehole image interpretation and breakout studies.
- Reservoir and resource characterisation, including geological mapping, coal reserve assessment, seismic interpretation, structural evaluation, basin analysis and regional stress analysis.

- Environmental monitoring, including environmental impact analysis.
- Coal analysis, including permeability assessment, vitrinite reflectance (coal rank), combustion experiments, coal cleat and mineralisation.
- Geophysical surveying.
- Hydrogeological studies, including borehole pump tests and monitoring, groundwater assessment and fluid flow modelling.
- Information technology expertise, including GIS applications and 3-D modelling of subsurface reserves.
- Training services in CBM.
- Risk assessment and risk management.
- Project management and planning.
- Project life-cycle analysis, from exploration to post-extraction.

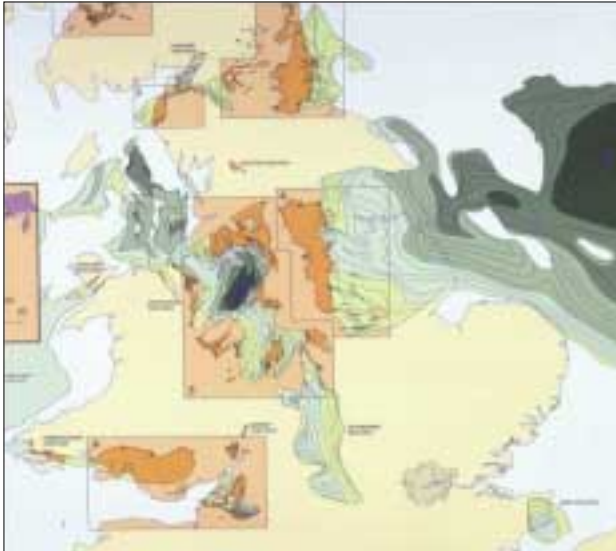


Figure 14. Part of the BGS 1:1,500,000 coal resources map of Great Britain (courtesy of BGS)

The BGS is a recognised centre of excellence for laboratory-based analysis and can offer a variety of analyses and support to CBM investigations including:

- Analytical Geochemistry Laboratories - geochemical interpretation of inorganic and organic data.
- Hydrothermal Laboratory - capable of simulating high temperature and pressure chemical reactions.
- Geotechnical Laboratories - offers both standard (eg BS 1377) and specialised tests in soil and rock mechanics, geophysics and sediment analysis.
- Aquifer Physical Properties Laboratory - can provide porosity, pore-throat size distribution, grain density, bulk density and total pore (surface) area by liquid resaturation and mercury injection capillary pressure tests, and gas and liquid permeability measurements.
- SEM, CL, XRD and ICP-MS facilities.

Cranfield University

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The Group has an interest in the catalytic destruction of CBM to restrict greenhouse-gas emissions and also to provide a thermal energy source for raising steam or power production via gas turbines or other heat engines. In the case of combustion devices this includes monolith and porous matrix combustors and their implementation in, for example, gas turbines.

Imperial College of Science, Technology and Medicine (ICSTM)

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Website: www.huxley.ic.ac.uk/research/envmin/emerg.html

Through its research into CBM since the late 1980s, the team at ICSTM is internationally recognised as a multi-disciplinary research centre dealing with CBM technology. A number of projects funded by the UK Research Councils, the UK DTI, the European Commission and industry led to the development of a unique methane simulator (METSIM), which is the only dedicated in-house CBM software developed in Europe. METSIM is a non-equilibrium sorption model, which accounts for methane adsorption and desorption and its flow in the matrix and fracture using a multi-media approach. This coupled wellbore rock mechanics and CBM reservoir simulator is unique in its treatment of stress and pore pressure dependent permeability, both at the wellbore and in the reservoir. METSIM enables the assessment of flow, stress and deformation in the wellbore region of vertical and horizontal CBM wells, as well as modelling/assessing cavity completions. METSIM has been used by the DTI Oil and Gas Division in its assessment of the CBM licences in the UK.

In recent years, the team at ICSTM applied this technology to the characterisation of abandoned coal mines as reservoirs and has successfully collaborated with SDK Saar to implement METSIM for the assessment of CMM production in the Saar region of Germany. Current experimental and numerical research involves the characterisation of the sorption and flow characteristics of binary gas mixtures in coal, for the development of ECBM and CO₂ STORAGE simulators.

Examples of current and recently completed research projects are as follows:

- 'Assessment of hazardous gas emissions to the surface over former mined areas' (Current - 2001).
- 'An investigation into the effects of matrix swelling on coal permeability for ECBM and CO₂ storage assessment' (Current - 2001).
- 'Investigation into the basic scientific phenomena of CO₂ injection and retention in coal for CO₂ sequestration and ECBM recovery', Industrial Partners: BP Amoco; DSK Saar; IFP, Wardell Armstrong (Current - 2001).
- 'Methane production simulation from abandoned mines', Industrial Partner: DSK Saar (Current - 2001).
- 'An investigation into horizontal borehole technology for improved CBM recovery' (1997-99).
- 'CBM well stimulation-modelling and performance prediction' (1994-97).
- 'An experimental and theoretical investigation into CBM well performance prediction and stimulation modelling' (1993-96).
- 'Numerical simulation of methane flow in coal seams' (1990-93).

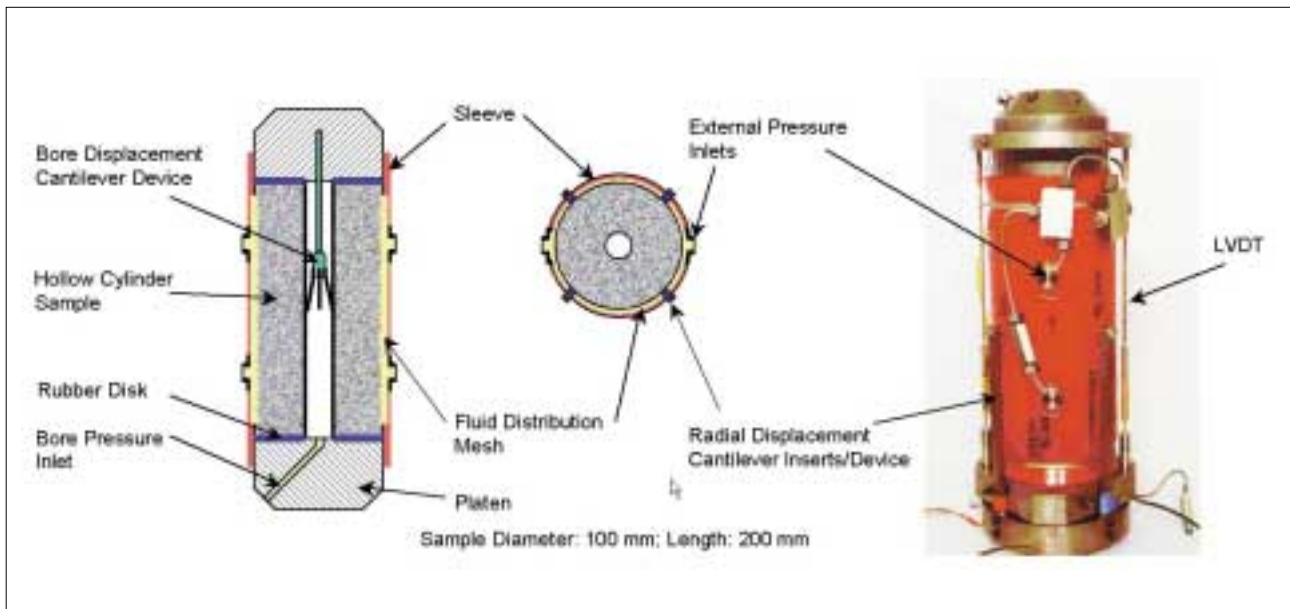


Figure 15. CBM open hole cavity completion experimental research (courtesy of ICSTM)

Loughborough University

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The University has expertise for and experience of the transfer of CBM technology to Russia and Ukraine. This capability is situated within the University's Business School and is accessed through Loughborough University Consultants, an independent company.

University of Cardiff

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CBM Research at Cardiff University focuses on factors influencing the drainage of CBM through open discontinuities within the coalbed, with particular reference to the South Wales Coalfield. The University works in association with commercial organisations to aid the siting of potential wells.

The South Wales Coalfield has high values of contained gas and considerable commercial interest has been shown in prospective CBM development in the area. The discontinuities considered by the Cardiff group include early formed, closely spaced cleat-fractures, joints and compressional deformation-related fabrics. The principal factor affecting drainage is openness, which is controlled by the attitude of the ambient *in-situ* stress field and the presence/absence of fracture-fill minerals.



Figure 16. Mineralised fracture in coal strata from Nant Helen open pit in the South Wales Coalfield. Minerals shown are quartz (pyramidal crystals), Ankerite (rhombic crystals) and Chalcopyrite (small dark crystals overgrowing the ankerite) (courtesy of University of Cardiff)

The research has involved computer simulations of fluid flow through the coal basin, to model the complex relations between fracture openness and fracture fill. In addition, desorption isotherms have shown that tectonically overprinted fracture sets increase the rate of desorption of methane from coal.

University of Nottingham

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The School's research capabilities in relation to CBM research include:

- Powerful computing facilities, including both mainframe and desktop computers, which are used extensively for numerical modelling applications such as CFD. Simulation of coupled strata fracturing and gas and water flow using these techniques is routinely carried out to investigate gas and groundwater emissions into underground mines and for CMM reservoir simulation.
- A 'methane' database containing extensive information on all aspects of CBM which has been compiled and will shortly be available for access by registered users via the School's web page.
- Laboratory testing facilities using a pseudo-stiff testing machine to determine coal and rock properties including the permeability of intact, fractured and highly fragmented rock under various stress conditions.
- Prediction of surface subsidence and rock mass behaviour induced by underground mining, a major factor which needs to be considered when estimating the extent of the voids which are available for the drainage of methane from abandoned coal mines, and when extracting methane from virgin seams.
- The extraction and utilisation of methane from abandoned coal mines: resources and reserve assessment, emission hazards and environmental impact studies.
- A wide range of gas monitoring and analysis equipment including portable FID, infra-red and thermal conductivity monitors for fieldwork and GC-MS and infra-red analysers for more accurate laboratory analysis. A portable system, which is safe in gassy atmospheres, has been developed for the measurement of gas flow and pressure in methane drainage boreholes.
- Laboratory facilities for the study of the gas sorption and desorption behaviour of coal and for the determination of gas content.
- Novel techniques to model the stratigraphic and diagenetic controls on trace element geochemistry within a coal basin, which could significantly influence CBM development. This is fully supported by an inorganic analytical facility (including X-ray fluorescence, inductively coupled plasma - mass spectrometry (ICP-AES) SEM, X-ray diffraction and atomic absorption spectroscopy (AAS)) as well as a microscope and image analysis suite.



Figure 17. Key staff from a UK-China CBM project at a VCBM site in China (courtesy of the University of Nottingham)

MISCELLANEOUS

European CO₂ Network (CO₂NET)

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Technology Initiatives is co-ordinator of the European CO₂ Network (CO₂NET). CO₂NET is a team of experienced European organisations and individuals with expertise in CO₂ issues, including enhanced CBM, that are planning, establishing and building the European CO₂ Thematic Network to facilitate co-operation between these organisations and, in particular, the European-funded CO₂ projects. CO₂NET is enhancing (and the resulting Thematic Network will enhance) the performance and impact of the projects and increase awareness worldwide of European activities and results in the capture and geological storage of CO₂, so fast tracking the developing technologies to help meet Kyoto emissions reduction demands. The Network web site can be found at www.ieagreen.org.uk under the 'practical research' item.

The Association of Coal Mine Methane Operators

e-mail: info@acmmo.org
Website: www.acmmo.org.uk

The Association of Coal Mine Methane Operators represents 13 companies involved with the extraction and use of methane from disused coal-mines to generate electricity.

| Names of organisations | Current CBM operator | Equipment manufacturers | Developers | Consultancy and related services | | | | | Universities/research establishments |
|--------------------------------------|----------------------|-------------------------|------------|----------------------------------|-----------|--|---|--|--------------------------------------|
| | | | | Drilling and associated services | Modelling | Geological services (including gas analysis) | Analytical Services (laboratory facilities) | Engineering services and general consultancy | |
| ACA Howe International | | | | | | | | | |
| AEA Technology Environment | | | | | | | | | |
| Alkane Energy | | | | | | | | | |
| ALSTOM Power | | | | | | | | | |
| British Geological Survey | | | | | | | | | |
| Cadogan Consultants | | | | | | | | | |
| Celtic Energy | | | | | | | | | |
| Clarke Energy | | | | | | | | | |
| Coastal Oil and Gas | | | | | | | | | |
| Coalbed Methane | | | | | | | | | |
| Cranfield University | | | | | | | | | |
| DEUTZ UK | | | | | | | | | |
| EDECO Petroleum Services | | | | | | | | | |
| Edinburgh Oil & Gas | | | | | | | | | |
| Energy Developments (UK) | | | | | | | | | |
| Evergreen Resources UK | | | | | | | | | |
| Farley Engineering | | | | | | | | | |
| First Energy | | | | | | | | | |
| GeoMet UK | | | | | | | | | |
| Hamworthy Combustion Engineering | | | | | | | | | |
| Harworth Mining Consultancy | | | | | | | | | |
| ICSTM | | | | | | | | | |
| International Mining Consultants | | | | | | | | | |
| Knight Energy Services | | | | | | | | | |
| Loughborough University | | | | | | | | | |
| MAN B&W Diesel, Ruston | | | | | | | | | |
| Octagon Energy | | | | | | | | | |
| PR Mariott Drilling | | | | | | | | | |
| Peter Brotherhood | | | | | | | | | |
| Pipeline Services | | | | | | | | | |
| Reeves Wireline Services | | | | | | | | | |
| Renewable Power Systems | | | | | | | | | |
| Rolls-Royce Power Ventures | | | | | | | | | |
| Schlumberger Evaluation & Production | | | | | | | | | |
| Scientific Analysis | | | | | | | | | |
| Scottish and Southern Energy | | | | | | | | | |
| StrataGas | | | | | | | | | |
| Technology Initiatives | | | | | | | | | |
| UK Coal Mining | | | | | | | | | |
| UK Gas | | | | | | | | | |
| University of Cardiff | | | | | | | | | |
| University of Nottingham | | | | | | | | | |
| Wardell Armstrong | | | | | | | | | |
| Warwick Energy | | | | | | | | | |
| Workington Gas & Light | | | | | | | | | |
| WS Atkins Consultants | | | | | | | | | |

NB The company data contained in this Capability Brochure have been provided by the organisations themselves. ETSU and the DTI have not made any checks on the accuracy of the data and shall not be held liable for any inaccuracies. This Capability Brochure is issued for the purpose of circulating the information made available by organisations that have indicated that they are active in the field of CBM.