Methane Combustion

Gas Engines	
COMPANY	**DESCRIPTION**
Mines often vent medium quality gob gas instead of using it, because gob gas requires enrichment and treatment prior to pipeline injection. However, fuel for power generators does not require pipeline quality gas. Generally, IC engines can be adapted to generate electricity using coal mine gas with a methane concentration as low as 25%. Regulations in most countries require a minimum of 25% CH_4 concentration for utilization and some require 30% CH_4. While all internal combustion engines powered by CMM are capable of producing electricity, several also have the capability for waste heat recovery and co-generation. For more information see: http://www.epa.gov/cmop/docs/ic_engine.pdf. There has been considerable consolidation among engine manufacturers in recent years and the list below in some cases includes different brands produced by the same manufacturer.	
Caterpillar www.cat.com/power-generation/generator-sets/gas-generator-sets (309) 675-0545 Joseph Allen allen_joseph_w@cat.com (309) 636-5556	Caterpillar has introduced a range of larger, more efficient gas generator sets that can be fueled by CMM, landfill methane, or natural gas. The CMM fueled CAT ™ G3520 Gas Engine produces 1966 kW with an efficiency of about 40% and NOx ratings as low as 0.5 g/bhp-hr. Minimum methane concentration for gas engines may be as low as 25%. Large installed base of CMM power generation, mainly in Australia and China.

Gas Engines	
COMPANY	**DESCRIPTION**
MWM http://www.mwm.net/en/ 49 6 213840 info@mwm.net Schaefer Heribert heribert.schaefer@mwm.net Armin Roeseler armin.roeseler@mwm.net	MWM, formerly Deutz Power Systems, was acquired by Caterpillar in 2011 and manufactures and markets under the name Caterpillar Energy Solutions. MWM's product portfolio manufactured in Germany comprises gas engines (gas generators or gas gensets) and plants in the output range from 400 kWe to 4,300 kWe. MWM can supply open or containerized units. Minimum methane concentration for gas engines may be as low as 25%. Large installed base of CMM power generation, mainly in Europe, the CIS, and in China.
GE Waukesha https://www.ge-distributedpower.com/ johnathan.blomberg@ge.com	Waukesha, a division of GE Distributed Power, manufactures three families of engines. The APG™, VHP®, and the VGF® include models designed to combust alternative fuels such as bio-gas, landfill, digester gas or CMM in addition to natural gas. Depending upon the model, the engines with attached generators (called Waukesha Enginator®) can produce from 165 to 1400 kW. GE also produces the Waukesha 275GL rated from 2300 to 3500 kW. https://www.ge-distributedpower.com/products/power-generation
GE Jenbacher https://www.ge-distributedpower.com/ Thomas Elsenbruch thomas.elsenbruch@ge.com +(43) 5244 600 2519	GE's Jenbacher gas engines manufactured in Austria range in power from 300 kW to 9500 kW and run on either natural gas or a variety of other gases (e.g., biogas, landfill gas, coal mine gas, sewage gas, industrial waste gases and other syngases). Minimum methane concentration for gas engines may be as low as 25%. Jenbacher engines are used in Europe, China, the CIS and Australia.

Gas Engines	
COMPANY	**DESCRIPTION**
Barbara Marschik barbara.marschik@ge.com +(43) 5244 6002607	https://www.ge-distributedpower.com/products/power-generation
IHI Corporation www.ihi.co.jp/en/products/energy_systems/index.html +81-3-6204-7724 https://contact.ihi.co.jp/index.php/ihi_eng/IHI/form_20302	The Nigata Gas Engine AG output ranges from 2,204 to 5,979 kW. This high efficiency gas engine series can combust fuels with low calorific value such as CMM, digester gas and landfill gas. www.niigata-power.com/english/products/gasengines/index.html
Mitsubishi Heavy Industries Ltd. https://www.mhi-global.com/ Nobuhiro Sawaki 81-3-6716-4496 nobuhiro_sawaki@mhi.co.jp Takaaki Furuya 81-3-6716-3490 takaaki_furuya@mhi.co.jp	Mitsubishi manufactures the GS16R-PTK and GS16R2-PTK gas engine/generator sets with output of 1000 kW and 1500 kW respectively. MACH gas engines are being used in CMM fired power generation projects in China. Mitsubishi also produces the MACH-30G series gas engines (KU30GA) that utilize minimum quantities of liquid fuel for ignition and have a generation output range between 3,650 and 5,750 kW. https://www.mhi-global.com/products/detail/product_explanation_gas.html https://www.mhi-global.com/products/pdf/ku30ga_en.pdf
Shengli Power Machinery Group Co., Ltd. http://www.generatorsetscn.com/ Manager Su sdjtsujie@gmail.com	Shengli Power Machinery Group, the earliest manufacturer of gas engines in China, produces gas engines that are very widely installed across mining regions in China to burn CMM. Shengli gensets come in 500kW and 600kW configurations capable of burning typical CMM gas drainage streams with concentrations above 25%. All CMM projects using Shengli gensets are concentrated in China.

Gas Engines	
COMPANY	**DESCRIPTION**
+86-15963081356	http://www.generatorsetscn.com/
Cummins Engine http://www.cummins.com/cmi/ (763) 574–5000 (800) 888–6626 ask.powergen@cummins.com	Cummins, a United States manufacturer, produces the QSV91 Series ranging from 1500 to 2000 kW through Cummins Power Generation, Inc. The series is designed specifically for lower BTU gas with target industries of landfill gas, CMM and biogas. http://cumminspower.com/www/literature/brochures/F-1523-LowBTUGensets-en.pdf
Dresser Rand Guascor http://www.dresser-rand.com/ (713) 354-6100 +33-156 26 71 71	Guascor® Low Quality Fuel Engines manufactured in Spain operate on a wide range of waste gases including landfill gas, biogas and coal mine methane. Power output ranges from 315 to 985 kW. Guascor engines are operating at a CMM project in the United States. http://www.dresser-rand.com/products/engines/

Gas Turbines	
COMPANY	**DESCRIPTION**
A wide variety of gas turbines may be fuelled with CMM or AMM. Normally turbines operate over a range of methane concentrations, but best results are achieved with a concentration above 35 % with minimal concentration variability. Large industrial gas turbines can have a generation capacity of 1,000 kW to 50,000 kW. Gas turbines operate by compressing and cooling air drawn into the unit. The compressed air is preheated through an exhaust heat recuperator and then mixed with fuel and combusted. The resulting hot gas expands through the turbine, producing the mechanical energy required to generate electricity and operate the compressor stage of the turbine. Most gas turbines require high inlet pressures, which raise methane's upper explosive limit; therefore, to ensure safe operation, methane concentration should generally be maintained above 40%.	
General Electric www.gepower.com Timothy J. Richards tim.richards@ps.ge.com	GE manufactures a wide range of heavy duty, small heavy duty, and aeroderivative gas turbines. Power output ranges from 43 MW to 470 MW. An 88-MW power plant (2 x 44-MW gas turbines) fueled by a mixed stream of coal mine methane and virgin coalbed methane operates in the United States as a peaking plant. https://powergen.gepower.com/plan-build/products/gas-turbines/index.html
Mitsubishi Hitachi Power Systems http://www.mhps.com/en/ https://www.mhps.com/cgi-bin/en/inquiry/index.cgi?code=10001&product=Technology	Mitsubishi Hitachi Power Systems, formerly Hitachi, manufactures the H-25 gas turbine (30 MW class) and the H-15 gas turbine (17MW class), which is a scaled-down model of the H-25 gas turbine. MHPS also offers small to large capacity combined cycle generators that use heavy duty gas turbines, from 6MW class to 300 MW class. http://www.mhps.com/en/products/category/gas_turbin.html

Gas Turbines	
COMPANY	**DESCRIPTION**
Kawasaki www.kawasakigasturbines.com Eiichi Harada 81-78-921-1679 harada@ati.khi.co.jp	Kawasaki manufactures a large variety of base load and stand-by gas turbines. The base load models range from 600 kW to 18 MW class while the stand-by turbines range from 600 kW to 4,800 kW class.
Rolls Royce www.rolls-royce.com James Loebig (317)230-3079 jim.loebig@liberty.rolls-royce.com	Rolls Royce manufactures a wide variety of gas turbine engines ranging from 4 to 64 MW in capacity. http://www.rolls-royce.com/about/technology/gas_turbine_tech/index.jsp
Solar Turbines mysolar.cat.com/ (619) 544-5352 https://solarmc.cat.com/ecom/showContactUs.do	Solar Turbines, a Caterpillar company, offers gas turbine engines (rated from 1,590 to 30,000 horsepower), gas compressors, and gas turbine-powered compressor sets, mechanical-drive packages and generator sets (ranging from 1.1 to 22.4 megawatts). https://mysolar.cat.com/cda/layout?m=41100&x=7

Microturbines	
COMPANY/TECHNOLOGY	**DESCRIPTION**
A microturbine consists of a small, air-cooled gas turbine connected to a high- speed generator and compressor on a single shaft. This simple design results in a system with a high power output, minimal noise generation, and efficient operation. Diesel, gasoline or kerosene can be used as alternate fuels to insure continuous electricity production in the event that the methane supply is disrupted. The generation capacity of microturbines can range 30 kW to 2,000 kW and the microturbine's 22-30% efficiency rating improves with the use of exhaust heat for preheating and adsorptive cooling.	
Capstone Turbine Corp. www.capstoneturbine.com 1 866 4 CAPSTONE (818) 734-5300 Rick Wade rwade@capstoneturbine.com	Capstone manufactures various sizes of Microturbines (i.e., 30kW, 65kW, and 200kW) that are scalable from 30kW to 10MW. Products based on the 200kW turbine are also available in 600kW, 800kW, and 1MW configurations. http://www.capstoneturbine.com/prodsol/products/
Flex Energy www.flexenergy.com info@flexenergy.com (877) 477-6937 Edan Prabhu edan.prabhu@flexenergy.com (949) 428-3832	Flex Energy's 250 kW Flex Turbine™ MT250 can operate efficiently on a broad range of gaseous fuels. Its newest 250SV Flex Turbine model will run with very low caloric value fuels such as methane/inert gas mixtures with as little as 30% methane by volume. http://www.flexenergy.com/flexenergy_flex_turbine.html

Microturbines	
COMPANY/TECHNOLOGY	**DESCRIPTION**
Ener-Core www.ener-core.com/ Michael Leone michael.leone@ener-core.com	Ener-Core has developed the 250kW Ener-Core Powerstation FP250 ("FP250"), and its larger counterpart, the 2MW Ener-Core Powerstation KG2-3G/GO, to economically abate emissions of Ventilation Air Methane (VAM) by enriching it with Coal Mine Methane (CMM) to generate electricity with near-zero emissions. The Power stations are specifically engineered for fuel flexibility (≥2.5% Methane Content) and modularity so that low-Btu gas sources can be used as an energy resource instead of wasted through venting and/or flaring. Ener-Core has successfully field tested the FP 250 on landfill gas in the U.S. and is actively targeting the CMM sector. http://ener-core.com/coal-mines-abandoned-closed-ventilation-air-methane/

Co-firing boiler for CMM and coal	
COMPANY	**DESCRIPTION**
Co-firing boiler for CMM and coal / low grade coal. Most co-firing boilers are found at mines where coal fired boilers are partially or completely retrofitted to burn mine methane. There are numerous CMM boiler installations located at mines around the world including in the UK, China, Ukraine, Russia and Kazakhstan.	

Co-firing boiler for CMM and coal	
COMPANY	**DESCRIPTION**
IHI Corporation (Energy & Plant Operations) www.ihi.co.jp/index.html Ryosuke Tsujimae (813)6204-7530 ryosuke_tsujimae@ihi.co.jp	IHI boilers are capable of using a wide variety of fuels, including fuel produced from waste materials, such as petroleum coke, residual oil and organic residues, and biomass in addition to coal, petroleum and natural gas.

Flaring	
COMPANY	**DESCRIPTION**
CMM flaring projects may employ open (a.k.a. "candlestick") or enclosed (a.k.a. "ground") designs. Both open and enclosed flares are designed with multiple redundant safety features such as flame and detonation arrestors to mitigate explosion risk. Open flares are simpler to design, install and maintain, reducing life-cycle costs. Enclosed flares consist of a vertical, refractory lined, combustion chamber which obscures the flame from public view. Enclosing the flame reduces thermal radiation from the flare at ground level, making it safe to work around, while increasing combustion efficiency. In addition, for some in the coal industry an enclosed flare also addresses aesthetic concerns.	
Abutec	ABUTEC manufactures and services Low Emission, Low NOx, Mine Gas Incinerators (i.e. Enclosed

Flaring	
COMPANY	**DESCRIPTION**
abutec.com/ Andy Smith (770) 846-0155 andy.smith@abutec.com	Flares) for the mine gas industry. ABUTEC specifically sizes and designs its flares to meet each site's unique mine gas needs with flares ranging in size from 10 scfm up to 6000 scfm. All ABUTEC mine gas flares meet United States EPA regulation 40 CFR 60.18 and are BACT approved. ABUTEC installed the first Mine Gas Incinerator in the United States.
Beijing Fairyland Environmental Technology Co., Ltd. http://www.fairyland.com.cn/en/profile.asp +86-10-62975118 fairyland@fairyland.com.cn	Beijing Fairyland Environmental Technology (FET) focuses on the recovery and utilization of low-thermal-value-gas (LTVG) including CMM. FET's flaring systems have been utilized for CMM projects in China. http://www.fairyland.com.cn/en/s_low_calorific_gas.asp?id=39
Biogas Technology Ltd. www.biogas.co.uk Ian Gadsby 44 1487 831 701 ian.gadsby@biogas.co.uk	Biogas Technology's Mine Gas Flare system builds upon the company's extensive landfill gas flare expertise. This enclosed flare can safely flare mine gas with 27-50% methane concentrations and is designed for total destruction of methane and associated hydrocarbons. Biogas flares have been used at CMM projects in Mexico and the United Kingdom. www.biogas.co.uk/flare.htm
BMF HAASE Energy Technology, Ltd. www.bmf-haase.de/en/ +49 4321 / 878-0 info@bmf-haase.de	BMF HAASE Energy Technology, Ltd., formerly Hasse Engineering, manufactures several low-temperature and high-temperature flare stacks suitable for CMM flaring.

Flaring	
COMPANY	**DESCRIPTION**
Hofstetter Umwelttechnik AG www.hofstetter-uwt.com/web/hofstetter/en.html Danny Langenberg danny.langenberg@hofstetter-uwt.ch	Hoffstetter's HOFGAS-CFM4c flare is able to burn methane concentrations ranging from 20 vol. % to 95 vol. %. For each specific project, the HOFGAS- CFM4c flare is designed for the defined gas mixture and the burner portion of the flare can be redesigned and modified in short time and at low costs if operating conditions change. The HOFGAS-CFM4c has a destruction efficiency > 99.95% in relation to methane gas achieved with combustion temperatures between 1,000 – 1,200°C and a defined residence time of > 0.3s. http://www.hofstetter-uwt.com/web/hofstetter/en/products/coal_mine/cfm4c.html
MRW Technologies, Inc. www.mrw-tech.com/ Mike Dearinger 918.827.6030 mdearinger@mrw-tech.com	MRW Designs and manufactures a wide variety of elevated/open and enclosed flare systems for all sizes and compositions of waste gas. MRW open flare systems have a destruction-removal efficiency (DRE) of 98%. If higher destruction is required, an enclosed flare system may be utilized if it is economically practical. The VOC Destruction Efficiency for MRW Enclosed Flares is guaranteed up to 99.99%+. http://www.mrw-tech.com/pia_elevated_flares.html http://www.mrw-tech.com/pia_enclosed_flares.html
Nanjing Carbon Recycle Biomass Technology Co., Ltd. http://www.rectec.com.cn/html/en/	Nanjing Carbon Recycle Biomass Technology Co. Ltd. manufactures 3 types of flares—mobile, open, and ground enclosed. The ground enclosed flare has been developed according to UNFCC technical requirements and is mainly used for CDM projects in which methane is destroyed by combustion. The highest capacity ground enclosed flare can process about 5000 Nm^3/h. Nanjing Carbon flares are used at mines in China. http://www.sxprice.org.cn/products/flares-z1be6c11.html

Flaring	
COMPANY	**DESCRIPTION**
Pro2 Anlagentechnik GmbH www.pro2.com http://www.pro2.com/s/22_123/page/modules/contact/index.php	Pro2 has decades of experience in the design and construction of high-temperature flares and emergency flares for landfill gas, biogas, sewage gas, and lean gas. Pro2 flares have been deployed in Russia, Ukraine, and Eastern Europe.
Questor Technology Inc. www.questortech.com/ John Sutherland jsutherland@questortech.com	Questor Technology engineers every incinerator to fit its specific application, based on gas composition and flow rates. Common configuration capacities range from 5 to 5,000 MSCF/D. Questor Incinerators have a combustion efficiency in excess of 99.99%. Questor has traditionally focused on oil field services and is now targeting the CMM and CBM sectors.

Gas conditioning systems	
COMPANY	**DESCRIPTION**
Drained CMM may contain large quantities of water and dust entrained within the gas. Combusting CMM without initial gas clean-up could lead to the combustion process equipment suffering from rapid degradation of the gas train, resulting in poor operational availability. Therefore, gas conditioning systems are sometimes used on the front end of a CMM use or destruction project to remove dirt, water, and control delivery pressure of the CMM. This significantly enhances the availability and reduces the maintenance of the CMM combustion plant.	

Gas conditioning systems	
COMPANY	**DESCRIPTION**
Beijing Fairyland Environmental Technology Co., Ltd. http://www.fairyland.com.cn/en/profile.asp +86-10-62975118 fairyland@fairyland.com.cn	Beijing Fairyland Environmental Technology (FET) focuses on the recovery and utilization of low-thermal-value-gas (LTVG) including CMM. In particular, its gas pretreatment systems remove impurities such as vapor, particles, and H2S, regulate the gas temperature, pressure, and flow and ensure stable and safety operation. http://www.fairyland.com.cn/en/s_low_calorific_gas.asp?id=42
Hofstetter Umwelttechnik AG www.hofstetter-uwt.com/web/hofstetter/en.html +31 20 740 09 99 +41 32 580 05 00 info@hofstetter-uwt.com	The HOFGAS-CPM is designed for degasification of coal mines with reliable processing of the methane gas for electricity or heat generation. The system is comprised of one or several blower stations and the necessary components for reliable degassing. Hofstetter gas treatment technology includes gas cooling and drying, filters, and gas compression. http://www.hofstetter-uwt.com/web/hofstetter/en/products/gas_treatment/gas_cooling_drying.html
Nanjing Carbon Recycle Biomass Technology Co., Ltd. http://www.sxprice.org.cn/suppliers/nanjing_carbon_recycle_biomass_technology_co_ltd-hzb21853.html	The Dehydrator and Dryer for CMM designed by Biomass Energy & Low Carbon Technology Research Center, Jiangsu and manufactured by Nanjing Carbon Recycle Biomass Technology, removes liquids, moisture, and other contaminants (e.g., sulfur) from CMM using refrigeration and adsorption methods. The Dehydrator and Dryer can achieve lower relative humidity and pressure dew points.
Pro2 Anlagentechnik GmbH pro2.com/ http://www.pro2.com/s/22_123/page/modules/contact/index.php	Pro2 compressor plants and disposal units with energy-saving rotary piston blowers are optimally adapted to disposal conditions and downstream gas utilization and gas disposal plants. Any required gas treatment – e. g. condensate separation, gas cooling/drying or gas purification – is designed for the required gas quality. Containerized plants also provide flexible adaptation capabilities. Pro2 gas conditioning systems are used for biogas treatment in Europe and could be used for conditioning of

Gas conditioning systems	
COMPANY	**DESCRIPTION**
	gob gas. http://pro2.com/t/22_98.html

Fuel Cells	
COMPANY	**DESCRIPTION**
A fuel cell is an electrochemical device that combines hydrogen fuel (can be CMM) and oxygen from the air to produce electricity, useable heat and water. Fuel cells produce Direct Current (DC) electricity without the conventional combustion reaction. A fuel cell is made up of an electrolyte member sandwiched between fuel and oxidant electrodes. A fossil fuel or biogas from which hydrogen is extracted is used for most common applications. The oxidant is typically plain air. The fuel is oxidized at the "anode electrode", releasing electrons that move to the "cathode electrode" via the external circuit. These electrons meet the hydrogen and push charged ions across the electrolyte. The charged ions (positively or negatively charged) move across the ion conducting electrolyte member, completing the electrical circuit. This electrochemical process requires very few moving parts, typically limited to air blowers and fuel/water pumps. Generation capacity is typically 100 kW to 300 kW.	

Fuel Cells	
COMPANY	**DESCRIPTION**
Fuel Cell Energy www.fuelcellenergy.com (203) 825-6000 info@fce.com btiby@fce.com Fuel Cells (general) www.fuelcells.org	Fuel Cell Energy Inc. manufactures the Direct FuelCell® (DFC). DFCs can run on coal mine methane. In addition, DFCs run on biofuels—gases from wastewater treatment, food processing, and landfills. DFCs emit virtually zero nitrogen oxide (NOx), sulfur oxide (SOx) or particulate matter and significantly reduce carbon dioxide (CO2) emissions. Developed exclusively for use in stationary applications, there are three main Fuel Cell Energy products designed to meet a variety of applications. All are self-contained electrical power generation system capable of providing high-quality baseload power with a range from 300kW to 2.8 MW. Standard efficiency is 47%. Fuel Cell Energy also manufactures a hybrid, multi-megawatt DFC-ERG™ (Direct FuelCell Energy Recovery Generation™) system that combines a Direct FuelCell® power plant with an unfired gas expansion turbine and achieves electrical efficiencies of up to 60%. A 200kW fuel cell plant has previously operated at an abandoned mine in Ohio, U.S.A. http://www.fuelcellenergy.com/products-services/products/

Drainage Gas Purification for Pipeline/Town Gas

Nitrogen Rejection	
TECHNOLOGY/COMPANY	**DESCRIPTION**
There are six basic processes that may be used to reject nitrogen, the major contaminant removed to upgrade CMM to pipeline quality. The technology chosen for removing nitrogen depends largely on a number of variables, including the volume of gas to be processed, the quantity of natural gas liquids present in the methane mix, and the nitrogen level in the gas. For more information, see EPA Publication EPA-430-R08-004 "Upgrading Drained Coal Mine Methane to Pipeline Quality: A Report on the Commercial Status of System Suppliers" www.epa.gov/cmop/docs/red24.pdf.	
Solvent Absorption Advanced Extraction Technology http://www.aet.com/home.htm Tom Gaskin, VP Technology (281) 447-0571 seekinfo@aet.com	The AET nitrogen rejection technology utilizes non-cryogenic absorption to separate methane and heavier hydrocarbons from nitrogen containing natural gases. For CMM, a solvent selectively absorbs methane while rejecting a nitrogen-rich stream in a refrigerated environment. The petroleum industry commonly uses selective absorption to enrich gas streams.
Pressure Swing Adsorption (PSA) CMM Energy LLC http://www.cmmenergy.com/ Peet Soot, PhD, PE	In most PSA nitrogen rejection systems, wide-pore carbon molecular sieves selectively adsorb nitrogen and methane at different rates in an equilibrium condition. For CMM, nitrogen is removed from low-quality gas by passing the gas mixture under pressure through a vessel containing an adsorbent bed that preferentially adsorbs nitrogen. Therefore, the gas coming out of the vessel is rich in methane. Since nitrogen is preferentially adsorbed during each pressurization cycle, the process recycles methane-

Nitrogen Rejection	
TECHNOLOGY/COMPANY	**DESCRIPTION**
President (503) 699-9836 cmm@cmmenergy.com TGPE Inc. www.tuckergas.com/nrupg03.htm (217)752-6420 tucker@adams.net	rich gas so that methane proportions increase with each cycle. PSA recovers up to 95 percent of available methane and may operate on a continuous basis with minimal on-site attention. PSA systems have excellent turndown capability so they are able to operate effectively with gas flowing at a fraction of rated capacity.
Molecular Sieve Guild Associates www.moleculargate.com Michael Mitariten (908)752-6420 mike@moleculargate.com	This process removes nitrogen, carbon dioxide, and part of the oxygen from the methane, whereas other processes remove the methane from the nitrogen. The process uses a type of molecular sieve that has the ability to adjust pore size openings within an accuracy of 0.1 angstrom. For CMM, the sieve pore size is set smaller than the molecular diameter of methane and larger than the molecular diameters or nitrogen, oxygen, carbon dioxide, and water. This permits the nitrogen and other contaminants to enter the pore and be adsorbed while excluding the methane, which passes through the fixed bed of adsorbent at essentially the same pressure as the feed. The molecular gate process employs a PSA operation. Guild Associates has installed twelve full-scale plants operating on methane from abandoned mines and gob gas, primarily in the Illinois, Central Appalachian and Northern Appalachian basins of the United States. Guild also has units operating at oil and gas operations, landfills, waste water and agriculture facilities in the United States, UK, Brazil, and the Philippines.
Cryogenic Separation BCCK Engineering, Inc. www.bcck.com	The cryogenic process uses a series of heat exchangers to liquefy the high-pressure feed gas stream. The mixture is then flashed and a nitrogen-rich stream vents from a distillation separator, leaving the methane-rich stream. To avoid the danger of explosion within the plant, designers locate a deoxygenation system at the plant inlet. Cryogenic plants have the highest methane recovery rate (i.e., about 98 percent) of any

Nitrogen Rejection	
TECHNOLOGY/COMPANY	**DESCRIPTION**
R. Clark Butts, P.E., President rcbutts@bcck.com Greg Hall, Sales Manager greghall@bcck.com Stephens T. Harper, VP – Corporate Development sharper@bcck.com (432)685-6095 Global Industrial Dynamics http://www.gidynamics.nl/ Chris van der Zande Business Development Manager +31 (0)71 56 174 13 (direct) +31 (0)71 56 202 56 (general) ccm.vanderzande@gidynamics.nl	of the nitrogen rejection technologies. Large-scale cryogenic plants have become a standard and economic solution for upgrading below-specification gas from natural gas fields, but they tend to be much less cost-effective at sizes below 5 mmscfd (142,000 m^3/d). BCCK Engineering is focused on the Americas and has installed three full-sized plants that upgrade CMM to pipeline quality gas in the United States. G.I. Dynamics (GID), a business partner of BCCK Engineering, and represents its cryogenic Nitech™ NRU technology as an integrated part of GID's Gas Processing Group in other areas of the world (Europe, Russia, Asia and Austria).

Nitrogen Rejection	
TECHNOLOGY/COMPANY	**DESCRIPTION**
Membrane Separation Membrane Technology and Research, Inc. www.mtrinc.com/nitrogen_removal.html Kaaeid Lokhandwala (650) 543 3360 Gas@mtrinc.com ProSep www.prosep.com (281) 504 2040 info@prosep.com	The process uses membranes, which are significantly more permeable to methane, ethane and other hydrocarbons than to nitrogen, to selectively pass the hydrocarbons while retaining nitrogen. A simple one-stage membrane unit would be appropriate for feed gas containing about 6 to 8 percent nitrogen, but more commonly (where nitrogen concentrations are higher) a two-stage membrane system is required. Inlet flow rates of between 0.1-20 MMscfd can be processed by MTR's NitroSep™ system with a product BTU recovery of 90%+. ProSep's sweetening membrane skids are modular in design and construction, lending themselves to easy scalability as production volumes and CO2 concentrations vary. As the produced gas passes across the membrane surface, there is little pressure drop from the inlet to the sales gas stream. http://prosep.com/solutions/gas/gas-treatment/gas-membranes/
CMM Concentration Technology Osaka Gas Co., Ltd. (Engineering Department) http://www.osakagas.co.jp/en/rd/technical/environment.html kyokoyam@osakagas.co.jp +81-6-6205-4589	Osaka Gas has two CMM concentration technologies: VPSA process using activated carbon (AC) and PSA process using Carbon Molecular Sieves (CMS). The VPSA process uses AC as adsorbent and can concentrate CMM (20-40% CH4) to about 50% CH4. The concentrated CMM can be used as the fuel for the gas engine. The PSA process uses CMS, which can concentrate CMM (50-80% CH4) to over 90% CH4. The concentrated CMM can be used as city gas or vehicle fuel. Off-gas can be also available as fuel for gas engine. VPSA using AC as adsorbent is commercially available while PSA using CMS as adsorbent is under development; the field test has been completed and the pilot test is planned.

Ventilation Air Methane (VAM) Mitigation and Utilization

Ventilation Air Methane (VAM) Destruction	
COMPANY	**DESCRIPTION/PROJECT INFORMATION**
Ventilation air methane (VAM) refers to the very dilute (<1% methane) ventilation air that is released from underground mine ventilation shafts. To ensure miners' health and safety, large volumes of fresh air are circulated through underground coal mines using ventilation systems to dilute in-mine concentrations of methane to levels well below explosive levels. This ventilation air is commonly vented to the atmosphere. Despite this low methane concentration, VAM is the single largest source of CMM emissions, representing more than half of all coal mining emissions worldwide. The priority for recovered coal mine methane is utilization; however, the very dilute methane concentration in VAM can make utilization very challenging. Absent a cost-effective use, destruction of methane still presents significant environmental benefit due to the reduction of greenhouse gases. The technologies listed below are regenerative thermal oxidizers (RTOs) and regenerative catalytic oxidizers (RCOs). These technologies were developed for use in the pollution control industry to destroy volatile organic compounds, odors, and other pollutants. Today there are thousands of RTOs and RCOs operating around the world in these applications. RTO and RCO technology have now been adapted successfully to the coal industry to destroy VAM emissions. The heat can be recovered for use in mine heating, district heating, power generation and dessicant cooling. However, most current applications at coal mines are destruction only.	
Biothermica www.biothermica.com Dominique Kay 514 488-3881 x228 dominique.kay@biothermica.com	Biothermica manufactures the VAMOX® RTO. The VAMOX® RTO converts VAM into carbon dioxide and water vapor. VAMOX® systems are tailored to meet site's specific needs. VAMOX® specifications include: • Unit capacity up to 140 000 scfm (238 000 Nm^3/h) • Methane concentration ranging from 0.2% to 1.2% • Up to 98% destruction efficiency

Ventilation Air Methane (VAM) Destruction	
COMPANY	**DESCRIPTION/PROJECT INFORMATION**
Dürr www.durr.com Jason Schroeder +1 (734) 254-2443 jason.schroeder@durrusa.com Dürr Clean Technology Systems www.durr-cleantechnology.com/application-range/coal-mining/ Karl Walby karl.walby@durrusa.com	Dürr manufactures several thermal oxidation (regenerative thermal, compact thermal, thermal exhaust) and catalytic oxidation (high-pressure, low-pressure, regenerative, and selective) air/exhaust purifier systems, as well as energy generation and combined heat/power systems (micro gas turbines and ORC units). For VAM destruction, Dürr has developed the Ecopure® RTO. Installed Ecopure® RTOs are treating roughly 1,000,000 scfm (470 m^3/s) of mine ventilation air in the United States and China.
Gulf Coast Environmental (GCE) www.gcesystems.com Mark Owen, VAM Manager (949) 783-0464 mowen@gcesystems.com	Gulf Coast Environmental manufactures the VAM CH_4 RTO. GCE uses a shipping container as the oxidizer shell, thereby reducing manufacturing costs.
Babcock & Wilcox MEGTEC www.megtec.com Ken Zak KZak@megtec.com	MEGTEC is a manufacturer of pollution control equipment including RTOs and RCOs. The MEGTEC VOCSIDIZER® is a compact and flameless regenerative single chamber thermal oxidizer (RTO) that generates high grade, super-heated steam from ventilation air with less than 1% methane. The unit has a flow capacity of 1,000 to 70,000 Nm3/h and destruction efficiency of 95 to 98%. MEGTEC equipment is in use at active mines in China and Australia and, previously, at an abandoned mine in the United

Ventilation Air Methane (VAM) Destruction	
COMPANY	**DESCRIPTION/PROJECT INFORMATION**
(920) 336-5715 Michael Hager MHager@megtec.com (920) 336-5715	States. Most VAM projects with MEGTEC equipment use the Vocsidizer®; however, MEGTEC also manufacturers a "2-can" RTO for VAM using a gas burner to pre-heat the oxidation chamber. www.megtec.com/ventilation-air-methane-vam
Shengdong New Energy Group Co., Ltd. shengdong.en.gongchang.com +86-769-86729610	Shengdong New Energy Group Co., Ltd. offers a VAM oxidizer that has been field tested for energy recovery (i.e., steam production) at several Chinese mines.
Canada's Centre for Mineral and Energy Technology (CANMET) www.canmetenergy-canmetenergie.nrcan-rncan.gc.ca/eng/ Eric Soucy Director, Industrial Systems Optimization Group (450) 652-4299 eric.soucy@nrcan.gc.ca Sindicatum Sustainable Resources www.sindicatum.com/ David Creedy, Ph.D. +86 10 6403 5880	CANMET has designed the CH4MIN ®, a regenerative catalytic oxidation (RCO) unit, specifically for VAM applications. The RCO (or Catalytic Flow Reversal Reactor (CFRR)) has the same basic design and operation as the RTO except that oxidation takes place in the presence of a catalyst at temperatures below the 1000°C needed for an RTO. Currently the design is destruction-only. CANMET pilot-tested a small-scale CH4MIN reactor. Sindicatum Sustainable Resources (SSR) holds the global license for the CH4MIN technology (except in Japan), and SSR built and laboratory tested a 54,000 Nm^3/h test unit from 2008 to 2009. The CH4MIN technology has not yet been deployed at an active mine, but a CH4MIN reactor is being constructed as part of a larger VAM project in China that will also include an RTO. http://www.sindicatum.com/portfolio_item/coal-mine-methane-china-duerping-vam-shanxi-province/

Ventilation Air Methane (VAM) Destruction	
COMPANY	**DESCRIPTION/PROJECT INFORMATION**
david.creedy@sindicatum.com	
HEL East Ltd. http://www.hel-east.com/ Neil Butler Design Engineer and Project Technical Development +44(0)1777712764 nbutler@hel-east.com	HEL-East has developed a Regenerative Thermal Oxidiser (RTO) that was designed in-house specifically for the abatement of coal mine VAM emissions. HEL-East designed, constructed, installed, and operated a commercial-scale RTO demonstration unit (90,000 Nm3/hr) for a period of time at a UK Colliery.

VAM Mitigation and Utilization as Combustion Air in Power Equipment	
COMPANY/TECHNOLOGY	**DESCRIPTION/PROJECT INFORMATION**
M.E.T.T.S – Consulting Engineers http://www.metts.com.au/ Dr. Michael Clarke +61-7-5502 8093 Michael.Clarke@metts.com.au	Fluidized beds suspend solid fuels on upward blowing jets of air during the combustion process. The result is a turbulent mixing of gas and solids. The tumbling action, much like a bubbling fluid, provides for high chemical reaction rates and heat transfer.
Corky's Sustainable Energy http://www.corkys.net.au/	Corky's VAM RAB® (Regenerative After Burner) unit treats VAM by a process of oxidation. The VAM RAB® is a patented Regenerative Thermal Oxidiser (RTO) coupled to the mine ventilation system via a safe connection duct. This system safely converts methane to carbon dioxide, which reduces the

David Cork +61 2 4960 8847 admin@thecorkysgroup.com.au	greenhouse gas impact of the fugitive methane emissions from an underground coal mine. A demonstration scale VAM RAB® with a full function safety duct has been constructed at an operating mine in Australia. The demonstration unit has a capacity of 12 m^3/s of VAM processing.

VAM Mitigation and Utilization in Turbines	
COMPANY	**DESCRIPTION/PROJECT INFORMATION**
Catalytic lean-burn gas turbines In general, the catalytic turbine intakes a very lean fuel/air mixture, compresses it, and combusts it in a catalytic combustor. The turbine operates at low temperatures, so it does not use combustion air for dilution and internal cooling, thus allowing the air intake to contain methane.	
CSIRO Energy Flagship www.csiro.au/Outcomes/Energy/Energy-from-coal/Advanced-coal-mining-technologies/VAMCAT.aspx +61 7 3327 4679 Dr. Shi Su Shi.Su@csiro.au	CSIRO developed the VAMCAT™, a lean-fuel gas turbine that employs a catalytic combustor to run on VAM concentrations around 0.8%. Depending on mine site specifications, for some field applications it will require the availability of supplemental fuel (e.g., drained coal mine methane). Supplemental methane can be blended in to increase the methane concentration entering the turbine to approximately 1 percent methane and can also be used to increase consistency in the methane concentration. CSIRO collaborated with various research institutions and manufacturers to develop the prototype unit under the Australian Government's Bilateral Climate Change Partnerships Program with the site support for Huainan Coal Mining Group. A 25kWe prototype unit built at CSIRO's Queensland Centre for Advanced Technologies was trialled at a mine of Huainan Coal Mining Group in China in November 2011, and the experimental data showed that the unit was operated with 0.8% methane in air (or a heating value of 0.288 MJ/m^3) with 19-21 kWe power output. www.globalmethane.org/expo_china07/docs/postexpo/coal_guo.pdf
Ener-Core	Ener-Core has developed the 250kW Ener-Core Powerstation FP250 ("FP250"), and its larger counterpart, the

VAM Mitigation and Utilization in Turbines	
COMPANY	**DESCRIPTION/PROJECT INFORMATION**
www.ener-core.com/ Michael Leone michael.leone@ener-core.com	2MW Ener-Core Powerstation KG2-3G/GO, to transform methane gas, especially "ultra-low Btu gas" from landfills, coal mines, oil fields and other low quality methane sources into continuous clean electricity with near-zero emissions. The Powerstations are specifically engineered for fuel flexibility and modularity, so that these low-Btu gas sources can be used as an energy resource instead of wasted through venting and/or flaring. The FP250 has been field tested on landfill gas. http://ener-core.com/coal-mines-abandoned-closed-ventilation-air-methane/
EESTech www.eestechinc.com Ian Hutcheson, CFO 61 7 3832 9883 ihutcheson@eestechinc.com	The Hybrid Coal Gas Turbine, HCGT, a rotary kiln system that burns waste coal with VAM or drained CMM, was jointly developed by Australia's CSIRO and Liquatech Turbine Company Pty in 2002 and was later purchased by EESTech in 2007. In this application, VAM is a supplemental fuel. The mixed fuel is combusted in a rotating kiln and the exhaust gases pass through a specially designed air-to-air heat exchanger. The heated clean air then powers a turbine to produce electricity. The waste coal feed can be adjusted as necessary in response to variations in VAM flow or concentration, thereby allowing for a constant energy feed to the turbine to power electricity generation. A 1.2MW gas turbine pilot plant was constructed at CSIRO's laboratory in 2002. The technology rights have now been acquired by EESTech, who is standardizing 10MW and 30MW systems and is seeking to commercialize the technology in China and India.

VAM Enrichment	
COMPANY	**DESCRIPTION/PROJECT INFORMATION**
Australian Coal Association Research Program (ACARP) www.acarp.com.au	Australian Coal Association Research Program (ACARP) and CSIRO have developed concentrators for VAM. Concentrators have been applied to several industries to capture volatile organic compounds. A concentrator of this type could be used to enrich methane in mine ventilation air to levels that meet the requirements of lean-burn methane utilization technologies, such as catalytic and recuperative gas turbines

VAM Enrichment	
COMPANY	**DESCRIPTION/PROJECT INFORMATION**
Samantha McCulloch +61 2 6273 6044 samantha.mcculloch@australiancoal.com.au CSIRO www.csiro.com.au Dr. Shi Su +61 7 3327 4679 Shi.Su@csiro.au	or even to levels that can be used in conventional internal combustion engines. Current efforts are focused on a VAM enrichment technology that uses honeycomb monolithic carbon fibers to achieve a 98% CH_4 removal efficiency. In this work, honeycomb monolithic carbon fiber composites were developed and employed to capture VAM with a large-scale test unit at various conditions such as VAM concentration, ventilation air (VA) flow rate, temperature, and purging fluids. Regardless of inlet VAM concentrations, methane was captured at almost 100%. Final methane concentration of 5 or 11 times were achieved in testing. Five-time enriched VAM can be utilized as a principle fuel for lean burn turbine. It can be further enriched by second step adsorption to more than 25%, which then can be used for commercially available gas engines. See more about concentrators in CMOP's brochure on concentrating Coal Mine Methane: www.epa.gov/coalbed/docs/concentrating-cmm.pdf

Modeling and Analysis

Modeling and Analysis	
COMPANY/	**DESCRIPTION/PROJECT INFORMATION**
Prediction of methane liberation and forecasting gas production in underground mines is an important tool in develop effective methane management programs at underground and surface mines. Effective gas prediction supports the health and safety of the miners, the protection of the mine's physical and mechanical assets, and the commercial prospects of the mine. Software is available to forecast gas production and assist mine owner/operators, CMM project developers, and others plan and develop gas drainage and utilization projects.	
Japan Coal Energy Centre (Resources Development Department) www.jcoal.or.jp/index-en.html tomita@jcoal.or.jp [1] Matsuyama@jcoal.or.jp [2] li@jcoal.or.jp [3] Hiroaki Hirasawa (813)6402-6106 jcoal-info@jcoal.or.jp	JCOAL offers three software packages to model gas liberation and methane emissions: [1]MGF – 3D: PC based simulation software for emission and recovery of coal mine methane developed by JCOAL. [2]COSFLOW: Computer simulation software for emission and recovery of coalmine methane developed by CSIRO and JCOAL. [3]KAZEMARU: PC-based simulation system to analyze mine ventilation network, developed by JCOAL. JCOAL also produces portable and compact gas analyzing apparatuses designed to measure gas contents in coal on site.
United States National Institute for Occupational Safety and Health (NIOSH)	The Office of Mine Safety and Health Research (OMSHR) in NIOSH has produced its Methane Control and Prediction (MCP) software to address some of the methane control issues in long wall coal mines in the

Modeling and Analysis	
COMPANY/	**DESCRIPTION/PROJECT INFORMATION**
www.cdc.gov/niosh Özgen C. Karacan (412) 386- 4008 cok6@cdc.gov	United States and other countries. The software contains ancillary models that will help predict total, as well as desorbable, gas content of coals and offers two sets of methane prediction models: a) Models for specific United States conditions, which directly relate to specific United States long wall mining conditions and to the mining operations in specific states; and b) Models for other United States/international conditions, which are applicable to "other United States" conditions and also to international projects. Version 2 has been available for download on the NIOSH website since September 2010 and can be downloaded for free. http://www.cdc.gov/niosh/mining/works/coversheet1805.html
Advanced Resources International, Inc. http://www.adv-res.com/ Anne Oudinot aoudinot@adv-res-hou.com (281) 558-9200	Advanced Resources' COMET3™ reservoir simulator for gas shale, shale oil, and coalbed methane (CBM) reservoirs, including pre-mine drainage, was developed in the early 1980's, and is available today. It has continually evolved to meet the changing needs of the unconventional petroleum industry. Advanced technical features include: (1) a triple-porosity/dual-permeability option for certain gas shale, tight oil, and coalbed methane (CBM) reservoirs, (2) multi-component sorption for enhanced coalbed methane (ECBM) recovery and carbon sequestration (CO2 sequestration) applications, and (3) a permeability model capable of modeling stress sensitivity. http://www.adv-res.com/COMET3_reservoir_simulator_for_gas_shale_and_coalbed_methane_CBM_reservoirs.php

CMM to LNG

CMM to LNG	
TECHNOLOGY	**DESCRIPTION/PROJECT INFORMATION**
Liquid natural gas (LNG) is formed by lowering the temperature of methane to -162°C. In its liquid form, LNG takes up 1/600th of the volume of methane in gaseous form. By condensing the methane into a high energy density liquid fuel it can be effectively stored and distributed by truck, rail or vessel. The liquefaction process removes the impurities such as carbon dioxide, sulfur compounds, volatile organic compounds, oxygen, nitrogen, and water. LNG is typically composed of over 95% methane, with the remaining 5% being nitrogen and other heavier hydrocarbons.	
LNG – Silesia (a joint venture by Prometheus Energy and CETUS Energetyka Gazowa) www.lngsilesia.pl +48 (0) 32 324 45 52 office@ingsilesia.pl Prometheus Energy www.prometheusenergy.com Matthew Barclay (832) 456-6500 info@prometheus-energy.com	The technology developed is applicable to small-scale operations on the order of 8 to 40 metric tons of LNG production per day. The process results in LNG production of > 90% methane. The installations are modified to handle CMM concentrations as low as 40%.

Drilling Techniques

Drilling Techniques	
TECHNOLOGY	**DESCRIPTION/PROJECT INFORMATION**
Effective gas drainage practices are important in CMM projects in order to decrease downtime due to gassy mine conditions, to maintain safer mine conditions, to create the opportunity to utilize more gas, and to reduce mine methane emissions. Methane drainage methods are conventionally classified as involving either pre-drainage or post-drainage techniques. Pre-drilling CMM drainage techniques can be used to reduce the in-situ gas content by reducing the gas content of the coal and adjacent gassy strata before mining occurs. The main methods of pre-mining degasification are: (1) vertical boreholes drilled from the surface, (2) in-seam boreholes drilled from within the mine, (3) superjacent boreholes drilled directionally from within the mine, and (4) in-seam boreholes drilled directionally from the surface. Post-drainage techniques involve capturing methane and other gases released from surrounding seams as a consequence of the strata movement, relaxation, and increased permeability induced by mining. Methane concentrations of 30% and higher should be achievable using post-drainage systems in all but the most challenging mining conditions, and concentrations of 60% and higher should be achievable from pre-drainage methods. For a more detailed discussion of drilling techniques and descriptions of active mine drainage projects in the United States, see USEPA's CMOP documents: "Coal Mine Methane Recovery: A Primer" and "Identifying Opportunities for Coal Mine Methane Recovery at U.S. Coal Mines: Profiles of Selected Gassy Underground Coal Mines 2002-2006".	
Vertical pre-drainage wells Atlas Copco Drilling Solutions LLC http://www.atlascopco.com/ Shane Lein Shane.lein@us.atlascopco.com	Coal seam methane (CSM), termed coal bed methane (CBM) in the United States, is drained from virgin coal seams several years (2-10 years) in advance of mining. Vertical wells are drilled from the surface to intercept coal seams. The wells may or may not benefit from stimulation such as hydraulic fracturing. Very high quality gas is produced from CBM wells, often with methane concentrations greater than 90%. Vertical wells are widely used in the United States, Canadian and Australian coal bed methane basins but have proven less successful outside of these countries where less permeable, deeper and more geologically complex coal seams increase drilling costs and decrease hydraulic fracturing success. Due to cost, vertical pre-drainage wells are usually drilled where infrastructure exists to use the gas, for

Drilling Techniques	
TECHNOLOGY	**DESCRIPTION/PROJECT INFORMATION**
Schlumberger http://www.slb.com/ Charles M. Boyer II boyer@pittsburgh.oilfield.slb.com Halliburton http://www.halliburton.com/ Ronald Sweatman ronald.sweatman@haliburton.com Weatherford http://www.weatherford.com/	example natural gas pipeline injection or power generation. Vertical wells drilled into virgin coal seams often produce large amounts of water and only small amounts of methane during the first several months in operation. As more water is removed, and the pressure in the coal seam is lowered, methane production increases. Produced water must often be treated before it can be disposed. Vertical wells are usually spaced on a regular grid pattern, such that drainage radii overlap, to most efficiently enhance the dewatering process and reduce the coal seam hydrostatic pressure. Operators may also perform multi-seam completions using the same well bore.
Surface to inseam (pre-drainage) (coal seams below the surface) REI Drilling http://www.reidrilling.com/ Daniel Brunner dan@reidrilling.com Valley Longwall http://www.valleylongwall.com.au/	Directional drilling technology can be used to drill from the surface horizontally through a target coal seam. The horizontal well bore intercepts previously drilled vertical wells, which produce water and gas to the surface. Multiple horizontal legs can be drilled from one well pad in different directions. Within the coal seam, laterals can be drilled from the main boreholes resulting in wide coverage. Similar to vertical pre-drainage wells, multi-seam completions can be drilled using surface to inseam drilling. This type of degasification can be especially valuable in fairly thick, uniform coal seams where folding, faulting and igneous intrusions are absent. Although hydraulic fracturing of surface to inseams wells is common in other formations, fracking of horizontal boreholes is generally not necessary in coal seams. The use of laterals and favorable geology allow for sufficient pre-mine degasification. Surface to inseam drilling of coal seams has been largely practiced in the United States and Australia where geologic conditions are very favorable for this type of drilling. Gas quality is very high coming from virgin seams,

Drilling Techniques	
TECHNOLOGY	**DESCRIPTION/PROJECT INFORMATION**
drillingsales@vli.com.au + 612 4964 2300 Target Drilling Inc. http://www.targetdrilling.com/ Steve Kravits stevekravits@targetdrilling.com Scientific Drilling http://scientificdrilling.com Asif Yusifow asif.yusifov@scientificdrilling.com	and wells are drilled where end use options exist.
High-Wall Mining - Horizontal boreholes and surface to inseam drilling Target Drilling Inc. http://www.targetdrilling.com/ Steve Kravits stevekravits@targetdrilling.com REI Drilling http://www.reidrilling.com/ Daniel Brunner	A high wall in a surface mine develops as the mined coal seam drifts deeper below surface and a large wall of overburden sits on top of the seam. In some instances coal seams mined under the high wall hold substantial quantities of gas presenting the possibility of gas and rock outbursts. In these situations, coal seam methane can be drained from exposed high walls with horizontal wells drilled into the mined seam and possibly surrounding strata in advance of coal mining. High wall degasification has been practiced in the United States and Australia.

Drilling Techniques	
TECHNOLOGY	**DESCRIPTION/PROJECT INFORMATION**
dan@reidrilling.com	
In-mine pre-drainage (in seam, underground coal mining) Target Drilling Inc. http://www.targetdrilling.com/ Steve Kravits stevekravits@targetdrilling.com REI Drilling http://www.reidrilling.com/ Daniel Brunner dan@reidrilling.com	In-seam drilling involves drilling a series of methane drainage holes into the coal seam from underground roadways several months or years in advance of mining. Holes may be drilled in a fan formation, in parallel layouts, or directionally drilled and can vary in length from hundreds to over 1,000 meters. The boreholes are connected to an underground drainage pipe network which carries methane to the surface. Methane concentration varies from 60-80% depending on the quality of the borehole seals and drainage system. The most common in-mine pre-drainage methods are short cross-panel horizontal boreholes and in-mine long-hole directionally drilled boreholes. Cross-measure boreholes drilled at an angle above and below the mined seam also produce methane prior to longwall mine-through and then produce gas from the gob. In-mine drilling methods are used around the world.
Surface post-drainage (post mining/goaf, underground coal mining) Atlas Copco Drilling Solutions LLC http://www.atlascopco.com/ Shane Lein Shane.lein@us.atlas copco.com	Methane is collected from the goaf/gob following long wall operations. Surface gob vent boreholes are drilled vertically from the surface prior to mine-through and are completed with slotted casing above the mined seam. Initial reservoir pressure is usually sufficient to produce gas without supplemental vacuum pressure, but eventually a vacuum pump is attached to the well to draw gas to the surface. This results in drainage gas with a concentration of approximately 25-70% methane, with the well producing gas of high concentrations initially followed by a decline in CH4 concentration. Six months to two years is a common operational time frame for a gob vent borehole. Gas produced from surface vent boreholes may be gathered and used for boiler fuel, power generation

Drilling Techniques	
TECHNOLOGY	**DESCRIPTION/PROJECT INFORMATION**
Schlumberger http://www.slb.com/ Charles M. Boyer II boyer@pittsburgh.oilfield.slb.com Halliburton http://www.halliburton.com/ Ronald Sweatman ronald.sweatman@haliburton.com Weatherford http://www.weatherford.com/	or other direct use, or processed for gas pipeline sales. In addition, vacuum pumps on gob wells often run on gas produced from the well.
In-mine post-drainage REI Drilling http://www.reidrilling.com/ Daniel Brunner dan@reidrilling.com Target Drilling Inc. http://www.targetdrilling.com/	In-mine post mining drainage involves capturing methane released into the gob after the longwall passes. There are several methods practiced around the world, and in-mine post drainage is the most common form of degasification worldwide. Cross-measure boreholes: Drilled at an angle above and below the mined seam from an adjacent roadway, and cross-measure boreholes draw gas from the gob. Gas is transported to the surface using an in-mine gathering system. Cross-measure boreholes are common in Europe and the Former Soviet Union where mines are very deep, permeability is low and geology is complex, and have also been used in other mining regions. Short and long-hole in-mine directionally drilled gob wells: Horizontal boreholes drilled in-mine that produce gas from the gob and can be drilled cross-panel or along the length of the longwall panel,

Drilling Techniques	
TECHNOLOGY	**DESCRIPTION/PROJECT INFORMATION**
Steve Kravits stevekravits@targetdrilling.com	usually above the mined seam. Directionally drilled gob wells are used in Australia, the United States and China and have been demonstrated in other countries. Drainage galleries (superjacent methods): Galleries that are driven in a coal seam above the mined seam for the purposes of capturing gob gas following longwall mining. Drainage galleries can be new purpose-driven galleries or already existing galleries that had a prior use. The galleries are sealed and connected to the drainage system. Gob gas rises through the strata above the mined seam to the drainage galleries where vacuum pressure pulls the gas into the drainage system. Boreholes drilled between the gob and the drainage galleries may be used to enhance gas recovery. Drainage galleries are used in many countries as a primary and secondary degasification strategy.

For a more detailed discussion of drilling techniques and descriptions of active mine drainage projects in the United States, see USEPA's CMOP documents: "Coal Mine Methane Recovery: A Primer" (www.epa.gov/coalbed/docs/cmm_primer.pdf) and "Identifying Opportunities for Coal Mine Methane Recovery at U.S. Coal Mines: Profiles of Selected Gassy Underground Coal Mines 2002-2006" (live.unece.org/fileadmin/DAM/energy/se/pdfs/cmm/pub/BestPractGuide_MethDrain_es31.pdf).