Conducting Pre-Feasibility Studies for Abandoned Mine Methane Projects

Module 3 – AMM Resource Assessment

Welcome

The United States Environmental Protection Agency (EPA) developed this course in support of the GMI and in conjunction with the United Nations Economic Commission for Europe (UNECE).

What is the GMI?

The Global Methane Initiative (GMI) is a voluntary, multilateral partnership that aims to reduce methane emissions and to advance the abatement, recovery, and use of methane as a clean energy source.

GMI Partner Countries account for nearly 70% of total global manmade methane emissions, which is equivalent to approximately 5,000 MMT CO_2e.

This course introduces principles for assessing the potential of developing projects to mitigate Abandoned Mine Methane (AMM).

Conducting Pre-Feasibility Studies for AMM Projects: Course Modules

- Module 1: Introduction and Objectives
- Module 2: Gathering Mine Information and Data
- Module 3: AMM Resource Assessment
- Module 4: Production Forecasting and Well Testing
- Module 5: Mine Closure Design for AMM Production
- Module 6: Market, Financial and Risk Analysis
- Module 7: AMM Pre-feasibility Case Study.

AMM Resource Assessment

What You Will Learn

In this module, you will learn about:

- The purpose and role of a resource assessment in a pre-feasibility study.
- How to estimate the potentially recoverable gas reserves by detailing the elements of an AMM reservoir through applying the information and data gathered as described in Module 2, including information about mined areas from mining plans, coal depth and thickness from geological logs, initial methane content, and other data.

- How to assess AMM resources and reserves through a simple estimate and a composite model.
- The time-dependent effects of rising mine water on potentially recoverable AMM resources.

What are AMM Resources and Reserves?

- **AMM Resources** = total volume of gas available from un-mined coal and other sources in strata that has been de-stressed by longwall mining and is remaining after mining has ceased. Where non-caving methods of mining are used (for example, room-and-pillar), the AMM resources will depend largely on the permeability of the worked seam and adjoining strata. However, this training focuses primarily on longwall mines.
- **AMM Reserves** = gas recoverable, excluding flooded areas, at the maximum suction pressure that can be applied (50kPa to 70kPa for a tightly-sealed mine). In the absence of firm data, a first order estimate of reserves (recoverable gas) can be taken as 50% of the resource.

Resources that Lie Outside the License Area

Gas resources that lie outside the license area should be excluded from reserve estimates. Where gas-producing workings continue beyond the boundary of the license area, any additional gas captured can be considered to be a commercial bonus. In some countries, authorities may accept the "right of capture" in contiguous license areas.

Understanding AMM Reservoirs

What is an AMM Reservoir?

An AMM reservoir consists of coal seams and any additional gas-bearing rocks within strata de-stressed by former longwall coal extraction.

Characterization of the AMM reservoir is an essential first step in estimating the potentially recoverable gas reserves, after accounting for the effects of mine water recovery, flooding of connecting roadways, and engineering works for controlling air ingress.

AMM Reservoir Components

An AMM reservoir includes:

- Gas sources
    - Un-mined coal in both the worked seam and the coal bearing strata above and below that have been disturbed by mining
    - Other gas-bearing rocks disturbed by mining, including natural gas reservoirs
- Vertical extent of the disturbed strata
    - Typically, in longwall workings, the zones of disturbance from which gas (and water) flow extend to 150m above the workings and 40m below.

Longwall Characteristics

Longwall mines generally produce the greatest volume of AMM due to the fracturing caused by longwall caving and the resulting gas flows from seams above and below the mined seam (as shown on the previous slide). Not all longwalls are the same, and geological and mining conditions can result in different extents of the reservoir.

For example, the zone of disturbance can be lower in height than that which would be expected from the rule of thumb presented on the previous slide, leading to fewer gas sources and hence smaller CMM and AMM reservoirs than expected.

Geological and mining conditions that can result in different reservoir extents include:

- The occurrence of strong strata above the mined seam
- Use of short-longwalls (e.g., less than 150m in length)

AMM Reservoir Components (continued)

An AMM reservoir also includes:

- The quantity of AMM
  - The volumes of gas in all gas sources above goaf areas and potentially also below
- Void spaces
  - Void and fracture spacing in the abandoned workings release gas desorbed from the coal seam and mine water from aquifers disturbed during mining
- Interconnected goaf areas
  - All the goaf areas and voids are interconnected by the former access roadways that allow for gas and water to flow and for gas to be transported to an AMM production well or shaft

AMM Reservoir Stoppings

An AMM reservoir will include stoppings, but these will not necessarily significantly hinder AMM production rates:

- In an operational mine, stoppings (or barriers) are built to isolate worked out longwalls from the airways.
- Such stoppings are generally sufficiently leaky to allow gas to flow through when a pressure gradient is created, such as through the use of a gas extraction pump.
- If the number of stoppings is large enough, the combined flow through all the stoppings will allow significant AMM production rates to be achieved in many instances.
- This type of situation exists in most large abandoned deep mines.

Abandoned Mine Conceptual Gas Reservoir Model

Mined areas represent the AMM reservoirs linked by roadways leading back to the original shaft.

Production can be achieved by pumping gas from the shaft or from a borehole that intersects a mine roadway.

Importance of an AMM Reservoir Model

Geologically-based reservoir models are important as they help to estimate the volume of AMM in place (gas in place) in an abandoned mine prior to committing to the costs of testing.

Gas in place estimates are compared with the area under the decline curve (see Module 4) to help build a more complete understanding of the reservoir characteristics.

As mine gas is produced over time, reservoir pressure will decline, necessitating more pumping effort to maintain gas flow. Eventually, the pumps will no longer be able to maintain the required gas flow rate.

A reservoir model can help evaluate the impact of flooding, which is likely to be time-dependent, in both pre- and post-mine-closure studies.

Impact of Mine Water on AMM Reserves

In a closed mine, rising water will flood and isolate the lowest workings first and eliminate progressively higher gas sources over time. While it is technically possible to de-water abandoned mines by pumping water to the surface, this is not likely to be financially viable.

In some instances, there may be a narrow window of opportunity to extract AMM from a mine before all of the workings are flooded from groundwater inflows into the mine. Such mines may not be viable for project development.

The rate at which water enters and accumulates in the void spaces in the abandoned workings is a critical parameter in determining the time-dependent recovery of AMM and which will ultimately determine the life, and financial viability, of an AMM project.

Roadway Flooding

Roadway flooding may isolate some parts of the AMM reservoir from the production well and hence reduce the recoverable reserves.

One potential solution is to drill an additional production well. The likelihood of such occurrences and the associated cost must be considered in the financial assessment (see Module 6).

Module 5 explains how some of the risk can be mitigated by making special engineering provisions underground prior to mine closure.

Floor strata are subject to less disturbance than roof strata and are prone to water saturation. For this reason, residual gas in floor seams in the lowest workings is generally excluded from reserves estimates.

Example of Discrete Flooding and Decanting of Mine Water from Block to Block

The diagram below illustrates rising water in the left-hand block of workings which effectively isolates it as an AMM reservoir. Once full, water will flow along a roadway to initiate flooding of the right-hand block, which will progressively reduce its AMM production potential.

Resource Assessment Overview

Resource Assessments

A gas resource assessment for an AMM project refers to the estimation of coal and gas resources, including recoverable gas reserves from an abandoned mine complex.

Resource assessments can help project developers understand the volume of gas in place and the potential gas production capacity of the abandoned mine – but not production rates (which are considered in Module 4).

AMM resources are initially estimated based on the physical properties of coal, such as:

- Gas content
- Seam thickness
- Density

Understanding the Origin of Gas in Coal

Naturally-occurring gases found in coal seams generally consist of methane (typically 80% to 95%) with lower percentages of heavier hydrocarbon gases, nitrogen, and carbon dioxide.

Methane was formed as a result of chemical reactions taking place as organic matter was buried at depth and subjected to increased heat and pressure and transformed into coal.

The greater the temperature, pressure, and duration of coal burial, the higher the coal maturity and the greater the amount of gas generated. Today, the gas is adsorbed onto organic matter and is found in the pore space of coal and rock layers in the subsurface.

During a resource assessment, AMM project developers gather geological data to determine the volume and composition of gases remaining in the coal after mining has ceased and the mine has been closed and sealed.

Steps in a Resource Assessment

The steps and their order in a resource assessment depend on the availability, level of detail, and confidence in available data.

This module presents a logical workflow, as shown below, that is normally undertaken for gas resource assessments.

Typical Steps in a Resource Assessment

- Gather coal reservoir properties (depth, thickness, gas content, etc.) and compute un-mined coal volumes
- Calculate Gas in Place
- Estimate AMM resources in each worked area
- Assess impact of mine water on recoverable resource

Geologic Data Inputs: Regional Stratigraphy

Stratigraphy organizes bodies of rock spatially and chronologically according to their common characteristics.

Classification, correlation, and mapping of sedimentary rocks in the subsurface allows for the effective evaluation of seam thickness, depth, system continuity, and trend directions of the coal resources and gas-bearing formations.

Stratigraphic data that help interpret regional stratigraphy include:

- Representative core logs
    - Mined seams
    - Surrounding strata
- Coal characteristics
    - Proximate analyses
    - Rank
    - Mineral matter content
- Geophysical logs

Calculating Gas in Place

The primary objective of the AMM resource assessment is to estimate gas in place (GIP) after mining, because such an estimate provides the total volume of gas potentially available for recovery and use.

AMM projects may not be viable if the total GIP is too small, even if other factors such as permeability and porosity are favorable.

Using a GIP estimate, the project developer can make an informed decision to continue or stop a pre-feasibility or feasibility study.

GIP Equation

AMM project developers calculate GIP using four basic parameters:

- Area
- Seam thickness
- Coal density
- Residual gas content

GIP Equation: GIP = H x (1 – a) x Q_r x d x A

- H = Coal seam thickness (ft or m)
- a = Ash or dirt content (%)
- Q_r = Residual methane content, ash-free
- (ft^3/ton or m^3/ton)
- d = Coal density ((g/cm^3; ton/m^3)
- A = Area (hectares, km^2, acres)

GIP Calculation: Defining Seam Thickness

Geologic data inputs, including well log data and stratigraphic data, are used to construct coal isopach maps that show the thickness of the coal seam(s) throughout the mine area.

When calculating GIP, the density of the coal needs to be considered. This is because ash and other mineral matter that does not hold gas will increase the tonnage of coal calculated and potentially overstate the GIP if a density correction is not applied.

Coal density is generally derived from proximate/ultimate analyses conducted in a laboratory that determine ash content, moisture content, and other coal properties.

GIP Calculation: Ash Content

Ash is the non-combustible residue formed from the inorganic or mineral components of the coal.

Ash may be incorporated from the original swamp environment or washed or blown into the coal seam during accumulation.

Ash content data are often not available for all of the coal seams in a reservoir, in which case, ash content can be roughly estimated based on the geological description on the log. Alternatively, dirt bands within the seam can be excluded from the coal seam thickness considered, which is then referred to as the ‘clean’ coal thickness.

GIP Calculation: Moisture Content

Most coals have some amount of moisture associated with them, ranging from 5% to 70%. Generally, the higher the rank, the lower the moisture content

Moisture reduces the amount of pore space available for gas and reduces the capacity of the coal substance to adsorb gas. However, so-called "inherent moisture" is a natural constituent of in-situ coal and adsorption isotherms representative of coal seam conditions are measured on coal retaining its natural moisture.

GIP Calculation: Assessing Gas Content

Methane content is important because it defines the quantity of methane in a ton of coal before disturbance in situ. An empirical calculation is then used to estimate the residual methane content after mining (AMM). The volume of AMM can then be extrapolated over the abandoned mine area to determine the total GIP.

In situ gas content is usually expressed in cubic meters of methane per tonne of coal (m^3 /tonne of coal) or cubic feet per ton of coal (ft^3/ton of coal).

Gas content values can be standardized by correcting to an ash-free basis, but not moisture-free as inherent moisture is a coal property.

For a pre-feasibility or full feasibility study, the project developer may obtain gas content data from the mine owner/operator, a geological survey, or another source.

Accounting for Gas Sources Other Than Coal Seams

Sometimes, more gas is present than can be accounted for by coal seam sources alone.

Indicators of extraneous gas sources in addition to coal seam sources include:

- Interpreted geophysical logs – gas-filled porosity
- Higher than expected gas emissions during mining
- Known gas-bearing sandstones in the mining sequence

Assessing Residual Methane (AMM) Content

During pre-feasibility studies, it is usually cost-prohibitive to drill and take cores from abandoned mine workings to directly determine residual methane content.

Instead, original seam gas content data are used and an empirical calculation, based on proven principles, is made to estimate residual methane content.

Residual gas content (Q_r) of unworked coal, after mining has ceased, is estimated by multiplying the initial gas content (Q_i) by an attenuation factor (f).

The closer a roof or floor seam is to the worked seam, the more of its gas will have been emitted during mining, and hence the larger the factor.

- f=0 at the mined seam
- f=1 at the limit height of the degassing zone

Assessing Residual Methane (AMM) Content (continued)

Making the simplifying assumption that f is proportional to the distance of a coal seam from the worked seam (relative depth, RD) then:

- fr (attenuation factor roof) = RD/150 for roof seams
- ff (attenuation factor floor) = RD/40 for floor seams
- For any roof seam, $Q_r = Q_i$ x RD/150 (RD<150m)
- For any floor seam, $Q_r = Q_i$ x RD/40 (RD< 40m)

Where the degassing zones of workings in two seams overlap, the product of the factors is used.

GIP Calculation: Area

Area represents the size of the in-situ coal seams that have the potential to store gas.

Area can easily be calculated using digitized maps or assessed manually from printed maps.

It is measured in either hectares, km^2, or acres.

De-stressed Zones Between Workings

The cross-section graphic on this slide shows that a coal seam can be disturbed more than once by mining.

Each time it is disturbed, more gas is lost.

It is important to take these effects into account when estimating AMM GIP.

Methodologies for Estimating AMM Resources

Methodology Properties

A suitable methodology for estimating the potentially recoverable gas from a mine or interconnected group of mines will have the properties below. It will:

- Be based on sound physical principles and a conceptual AMM reservoir model.
- Use traceable data sources wherever practicable.
- Be easily revised as more information is gained.
- Rely on a conservative approach to recognize inherent uncertainty and account for potential risks.
- Clearly state assumptions.
- Be a replicable process.

Estimating Resource and Reserves

The two approaches to estimate AMM resources and reserves are based on similar reservoir concepts and include:

- Simple first-order estimate
- A composite model

We will learn more about each approach on the upcoming slides.

First-order Estimate of AMM Resources

A simple, first order estimate of AMM resource volume (V_r) can be made using information from mine plans, geological logs, or shaft sections, and initial in situ methane content data.

V_r = sum of longwall areas x sum of unworked coal thickness above and below the worked seam (within the de-stressed zone) x Q_d

Where Q_d is the desorbable gas (m^3/m) which can be roughly estimated as:

- $Q_d = Q_i \times 0.25$ for multiple seam workings
- $Q_d = Q_i \times 0.5$ for a single seam working

Where Q_i is the average initial in situ gas content.

The recoverable reserves are roughly estimated as 0.5 V_r.

Composite Model for Estimating AMM Resources

A more detailed estimate involves a composite model, which uses information and data gathered (as discussed in Module 2) to calculate coal resource, gas resource, and void space in individual seam workings, accounting for overlapping de-stressed zones and mine water constraints. The model requires the following data:

- Mine plans for all worked seams
- Geological borehole logs and shaft sections
- Gas contend data
- Mine water flow data (excluding the service water component)

There are six stages of data extraction and calculation, and they will be discussed in the upcoming slides.

Composite Model – Stage 1

Base Plan

- Prepare a base plan and individual seam overlays showing all areas of coal extraction.

- This can be done manually or computationally using digitized plans, which will be illustrated on an upcoming slide.

Composite Model – Stage 2

Coal Seam Geology

- Prepare two or three composite geological logs, representative of the study area.
- The composite logs should show coal seam depths and typical 'clean coal equivalent' seam thicknesses (seam thickness adjusted to zero dirt or ash).

Composite Model – Stage 3

Sub Areas of Workings

- Subdivide the area into vertical groupings of worked seams and determine the areas of workings in each seam.

Example of Key Reservoir Parameters

A digitized base plan shows key parameters that are used to calculate residual gas content and coal volume when using the composite model.

Each color represents a sub area involving a different number of overlapping worked seams. Residual gas contents are calculated for all unworked coal in each sub area using the empirical formula presented on the next slide.

Composite Model – Stage 4

Key Reservoir Parameters

Residual gas contents (Q_r)

- For any roof seam, $Q_r = Q_i \times RD/150$ (RD<150m)
- For any floor seam, $Q_r = Q_i \times RD/40$ (RD< 40m)

Where Q_i is the initial gas content before mining and RD the vertical distance of the seam above or below the worked seam.

Coal volumes (V_c)

- The volume of unworked coal disturbed by coal extraction in each seam sub area ($V_c = A \times H$)

Where A is area and H is clean coal thickness.

Composite Model – Stage 5

Potential Resource

- Not all of the resource will be recoverable, even if accessible. AMM reservoir flow will decline until further extraction becomes unviable.
- For modeling purposes, a final suction pressure of 50kPa can be assumed. A typical value for q_a is 0.4 m^3/t at an assumed final void pressure of 50kPa, derived from a sorption isotherm.
- The recoverable gas volume, V_r, in m^3 in each seam sub area is estimated as:
    - $V_r = (Q_r – q_a) \times d \times V_c$
- where Q_r is residual gas content (m^3/t), q_a is the gas adsorbed at the final void pressure (m^3/t), d is coal density (t/m^3), and V_c is coal volume (m^3).

Example AMM Resource Estimation Sheet

Seam Number	Seam Thickness (m)	Initial Gas Content (m^3/t)	Relative Depth to Seam 12 (m)	Attenuation Factor	Residual Gas (m^3/t)	Desorbed Gas (m^3/m)	Coal Volume (MMm^3)	Available Gas (MMm^3)
20	0.4	10	150	1.00	10.0	12.1	1.7	20.8
18	0.85	10	100	0.67	6.7	7.8	3.7	28.5
15	0.3	10	68	0.46	4.6	5.0	1.3	6.5
14	0.3	10	30	0.20	2.0	1.7	1.3	2.2
13	0.4	10	14	0.9	0.9	0.3	1.7	0.5
12	0	10	0	0.0	0.0	-0.9	0.0	0.0
11	0.75	10	-12	0.30	3.0	3.0	3.2	9.6
10	0.65	10	-40	1.00	10.0	12.1	2.8	33.8
						TOTALS	15.7	101.9

The table above shows the initial gas content, residual gas content after mining, and available gas for AMM exploitation from the mined seam, Seam 12 (highlighted in orange), and all coal seams above and below the mined seam that influence gas emissions into the mine workings. Although there is no remaining gas to be recovered from Seam 12, there remains 101.9 million cubic meters of AMM resources due to the residual gas in the seams above and below the mined seam.

Composite Model – Stage 6

Mine Water Constraints and Reserves

- Mine water fills the lowest mine working first and progressively rises to higher mine workings. Once a working level is flooded, the means of transmitting and recovering the gas is removed. In addition, the hydrostatic pressure will eventually halt gas desorption from coal sources.

- When the mine water volume equals the void volume (V_v) in a particular worked seam area, the gas resource volume becomes zero.
- The AMM reserve is the estimated total methane that can be recovered after discounting the quantities of AMM that will be trapped as a result of rising mine water. Because the degree of flooding is time dependent, the reserve will decrease the longer the start of production is delayed.

Composite Model – Stage 6 (continued)

Void volume (V_v) is estimated for each worked seam

- V_v = area of mined out longwalls x extraction height x F/100

The factor F represents the proportion of the extraction that remains open as pore and fracture space in the goaf and as open space in roadways after mining.

- A value of F=20 is suggested for abandoned deep mines in the UK (Kershaw & Whitworth, 2005) and will be generally applicable in similar geology and mining settings elsewhere.
- However, the value may need to be adjusted on the basis of local experience.

AMM project life

Using the total void volume and water inflow rate, the time (in years) until the mine is totally flooded can be estimated. Thus, an indication of the potential life of an AMM project is obtained.

Resources to Manage AMM Estimate Uncertainty

Relying on either modeling approach will require access to reliable data and an understanding of the geological features of the mine and the mine layout, particularly the roadways and goaf areas.

A first-order assessment can be done relatively quickly at low cost by relying on mine-specific data as inputs into an engineering equation, but it will produce results that are invariably more uncertain.

To reduce uncertainty, a developer can prepare a composite model using more detailed data as inputs into software packages and estimation spreadsheets that are specifically designed for this purpose.

Composite Model Results

Although the development of a composite model is more complex and potentially expensive to implement, it should produce a better estimate.

Given the high degree of uncertainty that often accompanies abandoned mines and AMM projects, the additional cost may be a sound investment. It may also be necessary to secure project financing.

AMM resource and reserve estimates carry considerable uncertainties, but they provide a strong indication of the likely potential of an abandoned mine for development.

Module 3 Summary

In this module, you learned about:

- Developing AMM and coal resource assessments.
- How to estimate potential AMM project life, as rising mine water will limit the life of a producing AMM reservoir.
- Comparing resource results with the resource estimate from integration of the empirical decline curve derived in Module 4.
- The concepts of the AMM reservoir and model that are essential when designing engineering measures prior to mine closure to optimize AMM production (as discussed in Module 5).

Be prepared to terminate the pre-feasibility study at this stage if the indicated AMM reserves are small or if a project life would be too short due to rapid flooding.

Thank You!

You have completed Module 3.

Glossary of Terms

Abandoned Coal Mine – A mine where the work of all miners has been terminated and production activity and mine ventilation have ceased. Mine shafts might be closed and sealed. For purposes of this document, a coal mine is referred to as “abandoned”, whether or not the mine was closed according to applicable legal requirements. The terms “abandoned mine” and “closed mine” have the same meaning. Abandoned mines are not expected to reopen.

Abandoned Mine Methane (AMM) – The gas remaining, and in some instances newly generated by microbes, in abandoned coal mines held in voids, coal seams and other gas bearing strata that have been disturbed or intercepted by mining operations.

Adsorption – A process by which molecules of a gas, liquid, or dissolved solid adhere to a surface as a thin film.

Adsorption Isotherm – An empirical relationship that represents the amount adsorbed as a function of equilibrium gas pressure at a fixed temperature between the concentration of a solute on the surface of an adsorbent to the concentration of the solute in the liquid with which it is in contact.

Airways – A passage for a current of air through the mine that is used to improve air circulation and quality.

Anthracite – The highest rank of coal, i.e., with the highest carbon content and energy density.

Aquifer – An underground layer of water-bearing permeable rock.

Ash Content – The non-combustible residue left after carbon, oxygen, sulfur, and water has been driven off during combustion. The remaining residue, or ash, is expressed as a percentage of the original coal sample weight.

Attenuation Factor – Estimated factor for how much gas remains in a worked coal seam.

Available Gas – Total amount of gas available from the AMM resources.

Bituminous Coal – A middle rank coal known for its high heating value that is between subbituminous and anthracite in quality.

Borehole – A narrow shaft bored in the ground, either vertically or horizontally.

Butt Cleats – Naturally occurring vertical joints in coal (vertical cleats).

Clean Coal Thickness – Measured thickness of actual coal with thickness of dirt, ash, and other impurities removed.

Coal Bed Methane (CBM) – Methane extracted from coal seams before mining occurs. CBM is also known as virgin coal seam methane or coal seam gas. It is widely considered an "unconventional" source of natural gas.

Coal Depth – The measured or approximate distance to the coal-bearing strata.

Coal Mine Methane (CMM) – Methane released from coal due to mining activities. Like CBM, CMM is a subset of the methane found in coal seams, but it refers specifically to the methane found within mining areas (e.g., within a mining plan), while CBM refers to methane in coal seams that will never be mined. Because CMM would be released through mining activities, recovering and using CMM is considered emissions avoidance.

Coal Seam – A bed of coal usually thick enough to be profitably mined.

Coal Thickness – The measured or approximate thickness of the coal-bearing strata. Measured from the top of the coal-bearing unit to the top of the underlying unit.

Composite Model – A model that uses more detailed information than a first order estimate. Composite models require a deeper understand of mine history and data.

Core – A cylindrical section of a naturally occurring substance, typically obtained by drilling through the subsurface with a hollow steel tube called a core drill.

Darcy Flow – The velocity of fluid described in Darcy's Law. Darcy's Law states that the velocity of a fluid traveling through a porous medium is directionally proportional to the pressure gradient.

Decline Curve Analysis – An estimation technique for reservoir production that was developed to extrapolate trends in the production data from oil and gas wells, first documented by J.J. Arps in 1945.

Degasification – The process of removing gases from a coal mine through ventilation or drainage.

Desorbed Gas – Gas that has already been released from the coal matrix.

De-stressed – Relief of pressure concentrations caused by mining or geological factors.

Dewatering – The practice of removing groundwater from a mine.

Diffusion – A measure of the mobility of gases from one gradient to another.

Discrete Flooding – Mine flooding that only affects a portion of the mine.

Face Cleats – Naturally occurring horizontal joints in coal (horizontal cleats).

Faults – Breaks in the earth's crust across which movement has occurred.

Feasibility Studies – A type of study for assessing the viability of an AMM project. This type of study is characterized by being thorough and investigating the economic and technical feasibility of project development. A report produced by such a study is considered “bankable”, i.e., documentation is sufficient to secure project financing.
First Order Estimate – An estimate in which simple assumptions are made using high level information.

Fissures – A fracture in the rock along which there is distinct separation.

Fracking (Hydraulic Fracturing) – The practice of injecting pressurized liquid into a rock formation to create fractures within the rocks and increase permeability. In some coal mining instances, incidental fracturing of coal can be induced through mining activities.

Fracture Spacing – Spacing of factures measured as the distance between the fractures along a line perpendicular to the average orientation of the fracture set.

Gas Composition – The gas composition of any gas can be characterized by listing the pure substances it contains and stating for each substance its proportion of the gas mixture's molecule count.

Gas Content – Volume of gas contained in a unit mass of coal and is generally expressed in cubic meters, at standard pressure and temperature conditions, per ton of coal.

Gas-In-Place (GIP) – The volume of gas stored within a specific bulk reservoir rock volume (e.g., coal).

Gas Production – The quantity of gas produced by pre-mine drainage and post-mine drainage boreholes and drainage galleries.

Gas Production Forecast – An attempt to forecast methane emissions from gas drainage systems using the following methods: basin-wide emission factors; generic gas content vs depth curves; mine-specific emission factors; probabilistic methods; engineering equations; reservoir simulation.

Geological Logs – A written and/or graphic record of the geologic data obtained from drillhole core and/or cuttings.

Geophysical Log – The collection of geological and hydrologic information in wells by lowering and raising probes on a wire. It is typically more useful to employ a suite of different geophysical logs when collecting information.

Global Methane Initiative (GMI) – Launched in 2004, the GMI is an international public-private initiative that advances cost-effective, near-term methane abatement and recovery and use of methane as a clean energy source in three sectors: biogas (including agriculture, municipal solid waste, and wastewater), coal mines, and oil and gas systems. Focusing collective efforts on methane emission sources is a cost-effective approach to reduce greenhouse gas (GHG) emissions and increase energy security, enhance economic growth, improve air quality and improve worker safety.

Greenhouse Gas Emissions (GHG) – The release of greenhouse gases and/or their precursors into the atmosphere over a specified area and period of time. May be labelled as anthropogenic (resulting from human activities) or naturally occurring.

Gob (Goaf) – Broken, permeable ground where coal has been extracted by longwall coal mining and the roof has been allowed to collapse, thus fracturing and de-stressing strata above and, to a lesser extent, below the seam being worked. The term gob is generally used in the United States; elsewhere, goaf is generally used.
Hard Coal – A broad term that refers to Bituminous and Anthracite coal. This term typically contrasts Brown Coal, or Low Rank Coal, which includes Subbituminous and Lignite coal.

Hydrocarbon Gas – Organic compound consisting of hydrogen and carbon found in crude oil, natural gas, and coal.

Hydrostatic Pressure – Pressure that any fluid in a confined space exerts.

Initial Gas Content – Original volume of gas contained within a mass or coal before mining operations.

In-Situ – It can mean "locally", "on site", "on the premises", or "in place" to describe where an event takes place and is used in many different contexts. For example, in fields such as physics, geology, chemistry, or biology, in-situ may describe the way a measurement is taken, that is, in the same place the phenomenon is occurring without isolating it from other systems or altering the original conditions of the test. The opposite of in-situ is ex-situ.

Isopach Maps – A map that illustrates thickness variations of a certain layer of rock or coal.

License Area – The area that the AMM project is legally permitted to produce from.

Lignite Coal – The lowest coal rank, characterized by a low heating value and a high moisture content.

Longwall – One of three major underground coal mining methods currently in use. Employs a shearer which is pulled mechanically back and forth across a face of coal that is usually several hundred feet long. This mining method can produce large quantities of coal and gas.

Low Rank Coal – A broad term for a rank of coal that encompasses Lignite and Subbituminous coal.

Metallurgical Coal – The grade of coal that is used to produce quality coke for steal manufacturing.

Methane – Methane is a potent greenhouse gas. Methane's lifetime in the atmosphere is much shorter than carbon dioxide, but it is 28-35 times as efficient at trapping radiation than $CO2$ over a 100-year period. Methane is the main precursor of ground level ozone pollution, and thus affects air quality. Methane is also an energy resource that can be captured and used. Methane in mines poses safety risks, due to its explosiveness when mixed with air.

Permeability – The state or quality of a material or membrane that causes it to allow liquids or gases to pass through it.

Pore Space – The free space between the mineral grains of coal.

Porosity – The measure of void or pores space present when a solid and is represented by volume percentage of void in the solid. It defines the maximum possible amount of methane that can be retained in the coal.

Pre-Feasibility Studies – Typically provide a detailed technical analysis of site-specific information and considers project financing. Provides a gas production forecast and a review of current gas drainage practices. However, this document provides less granularity than a full feasibility study. This document is typically not considered a "bankable" document.

Proximate Analysis – An assay of the moisture, volatile matter, fixed carbon, and ash content of a coal sample.

Rank – The classification of coals according to their degree of metamorphism, progressive alteration, or coalification (maturation) in the natural series from lignite to anthracite.

Regenerative Thermal Oxidizer – An industrial system that destroys volatile organic compounds in process exhaust air from the mine before it escapes into the atmosphere.

Reservoir Pressure – An indication of how much fluid (gas, oil, or water) is remaining in the reservoir. It represents the amount of driving force available to drive the remaining fluid out of the reservoir during a production sequence.

Reservoir Simulation – Provides a consistent and reliable way to account for the complex mechanisms of coal seam gas desorption and diffusion. Also provides the opportunity for field and laboratory data to be integrated into a single geologic/reservoir model to evaluate exploration and development strategies.

Residual Gas Content – The quantity of gas remaining in a sample of coal following a period of gas desorption.

Roadway – Any mine track used to transport material (coal).

Room-and-Pillar – A system of coal mining in which the coal is extracted from large open areas (rooms) with large portions unmined to support (pillars) the overlying rock.

Shaft – A vertical of near-vertical opening into the mine.

Stopping – A manmade barrier built into the mine to prevent air and gas from moving from one section of the mine to another.

Strata – A layer of sedimentary rock or soil; refers to a layer of coal in this instance.

Stratigraphy – The order and relative position of various rock layers.

Subbituminous Coal – A rank of coal with a low-to-moderate heating value; mainly used for electricity generation.

Suction Pressure – The intake pressure generated from gas pumps.

Suction Pumps (Gas Pump) – A pump used in Petroleum production responsible for drawing out liquids/gasses by means of suction.

Thermal Coal – The general term for coal that is used to produce electricity and heat.

United Nations Economic Commission for Europe (UNECE) – The UNECE is one of the five regional commissions under the jurisdiction of the United Nations Economic and Social Council. It was established in order to promote economic cooperation and integrations among its member states. The commission is composed of 56 member states, most of which are based in Europe, as well as a few outside of Europe.

United States Environmental Protection Agency (USEPA) – An independent executive agency of the federal government of the United States federal tasked with protecting human health and the environment.

Venting – Direct release of natural gas into the atmosphere.

Void – The area of excavation that remains after mining is complete.

Worked Seam – A coal seam that has already been mined or partially mined.