Measuring Methane Emissions from Coal Mines

Technical Guidance Document for Source 5: Drained Coal Mine Methane - Vented

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Introduction to Steel Metcoal Methane Partnership Technical Guidance Documents

Action on lowering the emission intensity of metallurgical coal mining is critical to limiting the impact of the industry on global warming. The aim of Technical Guidance Documents (TGDs) is to assist members of the Steel Methane Partnership (SMP) in standardising reporting of methane emitted from their assets while establishing a performance framework and action plan that achieves a rapid reduction of methane emissions, in accordance with an agreed schedule and defined targets.

This document is a part of a series that describes sources of methane emissions resulting from coal mining operations, as outlined by the SMP framework.

Source	Source of methane emissions
1	Pre-mine drainage
2	Surface Mine (Open Pit) Methane
3	Ventilation Air Methane (VAM) - Vented
4	Ventilation Air Methane (VAM) – Incomplete oxidation/utilisation
5	Drained Coal Mine Methane - Vented
6	Post-mining
7	Waste Coal Heaps
8	Strata Fracture Emissions
9	Closed and Abandoned Mine Emissions
10	Other Gas Infrastructure Losses

The TGDs are based on principles and are not intended to serve as detailed manuals. The global coal industry possesses a wealth of expertise and experience that should be harnessed to ensure the success of this initiative. Methane measurement methods for safety monitoring are well known and can be improved and expanded to provide more accurate quantification of emissions.

The guidance documents introduce suggested methodologies for quantifying methane emissions from specific sources and outlines established mitigation options.

List of Acronyms

CEMS	Continuous Emissions Monitoring Systems
CMM	Coal Mine Methane
IMEO	International Methane Emissions Observatory
SMP	Steel Methane Partnership
TGD(s)	Technical Guidance Document(s)
UNEP	United Nations Environment Programme
VAM	Ventilation Air Methane

SMP Source 5: Drained Coal Mine Methane – Vented

1. Overview

This TGD is dedicated to methane emissions described under SMP source 5 'Drained Coal Mine Methane (CMM) – Vented' and thus aggregates all underground drained methane in a coal mine that can be measured at point sources on the surface such as vents at methane drainage stations or at drained gas emission mitigation equipment.

Supplementary to the above, an outline of the in-mine contributing sources to these surface emissions from source 5 is also provided.

The scope of this TGD excludes methane emissions described under SMP source 1 'Pre-mine Drainage' and source 10 'Other Gas Infrastructure Losses' which include, among others, methane emissions from incomplete combustion in flares, methane emissions (leakages) from positively pressured surface pipelines, and emissions (leakages) at gas extraction stations other than venting.

2. Introduction to SMP source 5 'Drained Coal Mine Methane – Vented'

Strata disturbance caused by the longwall extraction of coal leads to the release of methane from the coal being mined, from de-stressed coal seams, from abandoned coal faces and other gas bearing strata above and below the worked seam. The faster the mining rate, the greater the rate at which roof and floor gas sources are disturbed and hence the greater the gas flow. Thus, the emission rate from a working longwall, averaged over a few months, is approximately proportional to the run-of-mine coal production. Emissions peak during sustained high production, during barometer falls, and then decline during periods of no production such as maintenance, weekends, holidays, and unplanned stoppages. Roof and floor emissions are usually substantially lower where partial caving methods are used; these mining methods involve leaving pillar support to limit ground movement and hence the volume of strata de-stressed by mining to release gas is, in most instances, greatly reduced compared with longwall extraction.

For general estimation (levels 1 & 2) of gas flows, a specific gas emission factor (SGE), expressed in cubic metres (m^3) of methane released per tonne of coal mined (SMP reporting levels 1 & 2) is used.

Mine safety laws require that the concentration of methane within the workings must not exceed statutory safety limits otherwise mining must cease, and the affected working area evacuated. Regulations vary from country to country in detail, but all are designed to ensure that methane concentration in working areas does not fall within the explosive range. Different countries apply different safety factors (UNECE, 2016). When methane emissions are too high for ventilation control alone, gas drainage techniques are employed to capture a portion of the gas released from the de-stressed surrounding strata.

Drained sources of coal mine methane

Methane may be drained from the following sources within a mine:

- Pre-draining coal seams: This involves drilling boreholes either underground or from the surface before mining of a given coal seam begins (includes in-seam drilling for panels prepared for longwall mining).
- Post-draining roof and floor seams: After mining, methane can be extracted from the roof and floor seams, as well as other gas-bearing layers that have been de-stressed due to mining operations. This can be achieved from underground or, where surface and geological conditions are favourable, from goaf boreholes.
- Sealed off mined out areas (sealed goafs and abandoned roadways): This refers to draining methane from areas within mines that have been sealed off after extraction. They typically consist of residual emissions from the roof and floor, along with methane release from any remnant coal in the worked seam. It is important to note that mining activities cause ground disturbance, making the seals imperfect, and under certain circumstances, methane can still flow through them.

Drained coal mine methane (CMM) typically includes a mixture of air that enters the system through strata fractures and imperfectly sealed boreholes. Prior to dilution the gas typically consists of approximately 80-95% methane, along with ethane, carbon dioxide, nitrogen and other trace gases. Drained gas may contain a significant ethane concentration but only the primary methane component is considered for SMP sources.

It is important to note that falling barometric pressure leads to an increased pressure gradient across the seals in the worked-out areas of the mine. Consequently, there is an increased flow of the gas mixture from behind the seals. This effect is likely to be more significant in old, extensively worked mines. It supplements the flow related to production but is independent of the mining rate.

Elevated drained methane flows can arise due to:

- Increased suction to increase methane flow from sealed areas (goafs and abandoned roadways) pending a forecasted rapid drop in atmospheric pressure (typically a few days at most).
- Mining activities encountering an additional gas source e.g., interaction with a fossil gas reservoir (can continue for months).
- Gas outbursts (virtually instantaneous).

Not only does the flow of drained CMM vary, but so does its concentration, which is crucial for ensuring the safety of gas transport, utilization, and mitigation. The explosive range of methane in air spans from 5% to 15%. A well-executed borehole design, installation, and sealing, together with careful pipeline management and suction control, should guarantee that the drained methane concentration remains at 30% or higher. This level ensures safe transportation through pipelines and enables its better utilization.

When unsuitable gas drainage methods and poor implementation standards are employed, it results in low drainage capture efficiencies and excessive air ingress. This, in turn, leads to the production of gas with low concentrations, occasionally falling within the explosive range. International guidance strongly advises against attempting to transport or use gas in the explosive range to avoid a catastrophic explosion that will endanger the lives of mine workers, cause structural damage to the mine, and result in substantial costs to the mining operation (UNECE, 2016).

Drainage techniques

There is a wide variety of gas drainage techniques (Appendix Table 5.1), (CEC, 1980) each with its own specific refinements. Gas can be pre-drained ahead of mining where coal seams are sufficiently permeable. In deep mines, it is common to post-drain a significant portion of the gas. This means extracting gas from the de-stressed zones (goaf or gob) above and sometimes also below the worked seam. This is achieved using inclined boreholes or horizontally directionally drilled steered long boreholes positioned above the worked seam. In some countries, gas drainage galleries are constructed above or below the worked seam.

The gas is brought to the surface through pipes under suction generated by extraction pumps specifically designed for safe handling of potentially flammable gas mixtures. The gas can either be vented to the atmosphere, flared, or piped to a utilisation plant for purposes such as power generation, co-generation, or direct use for mine heating, or transmitted to industrial users. Any unused gas at the utilisation plant is vented or may be destroyed. The vent stacks are usually equipped with flame traps to prevent flame propagation into the mine pipework (e.g., from lightning strikes) and a diffuser or 'hat' to disperse the vented gas.

Where the workings are relatively shallow, goaf boreholes may be drilled from the surface and connected individually or in groups to a portable extraction pump; these may be located at some distance from the shafts.

The captured gas is piped to the surface. In some mines, gas is drained within a mining district to an underground extraction station and subsequently released into a main ventilation airway where it is diluted to meet permissible concentration levels. The gas released in such a manner will appear at the ventilation shaft as VAM. It is important to note that this TGD only considers the quantification and mitigation of the methane captured and drained to the surface, excluding methane that is drained and vented underground that will appear as VAM.

Point emission sources at the surface

Once the methane has been drained to the surface, there are various potential venting locations, which may or may not be present, depending on gas drainage methods employed and any utilisation arrangements:

- Methane drainage station
- Surface goaf boreholes
- Surface pre drainage wells (fugitive emissions only if gas collected for use)
- At a full gas holder (storage tank)
- At a utilisation plant when gas supply exceeds demand or flare capacity is exceeded, where present.

Correlation of emissions with coal production is an essential element to facilitate levels 1 to 3 reporting, and for estimating emission reductions associated with any decrease in coal production rate or vice versa.

Drained methane emissions are aggregated with all other methane emission sources at a mine site for reconciliation with remote site level measurements to achieve level 5 reconciliation reporting.

3. Quantification Methodology

While distinct sources of drained methane within the underground mine can be identified, such granularity is not necessary for emission quantification. The sum of emissions can be measured at the drainage gas vents, at the pumping station, or at the extraction wells, plus and it should also include any venting associated with a utilisation plant.

Five SMP reporting levels have been defined, grading from a very general estimate to high precision measurements:

Level 1 – Emissions reported by aggregated source categories at a country level.

Level 2 – Emissions reported by aggregated source categories using available source-specific activity data and regional or country-specific emission factors (EFs), reported at a site level.

Level 3 – Emissions reported by detailed source type using available source-specific activity factors (AFs) and generic emission factors for a given source type derived from existing literature, engineering calculations, or source-level spot measurements.

Level 4 – Emissions reported by detailed source type using source-specific AFs and source-specific EFs established with source-level measurements taken at an appropriate sampling frequency for a given source type.

Level 5 – Emissions reported similarly to Level 4, but with the addition of reconciliation with total site-level measurements.

The methodology at each level applied to VAM emissions are defined below.

It needs to be noted that while Level 1 to 3 are based on lower IPCC reporting levels, they are of little value to inform on the scale of emissions, determining mitigation strategies and policies, as well as progression against the reduction targets. They are nevertheless presented here to help mine owners assess their current reporting schemes and encourage employment of more robust measurement techniques.

Level 1: Estimates of drained CMM flow

At SMP reporting level 1, national and global emission factors incorporate the total of ventilation air methane and any drained methane. It should be noted that due to the wide range of Emission Factors that can arise depending on the geology, level 1 estimates are of little value for setting targets or determining mitigation policy.

Calculations

Estimated drained flow = EF(g) x DF(g) x coal production, $m^3.year^{-1}$;

- EF(g) is a global emission factor $m^3.tonne^{-1}$,
- DF(g) is the estimated fraction of drained gas in the total mine methane (post drained methane plus VAM, no units.
- Coal production is the total coking coal production at the company level, $tonne.year^{-1}$.

Methodology

- For EF(g), IPCC Tier 1 offers the following range of global emission factors as a basis for best practice estimate of methane emission from coal mines ~~(IPCC, 2019):~~
  - Low methane Emission Factor = 10 $m^3.tonne^{-1}$
  - Average methane Emission Factor = 18 $m^3.tonne^{-1}$
  - High methane Emission Factor = 25 $m^3.tonne^{-1}$

  In practice, emission factors at different coal mines range from < 1 $m^3.tonne^{-1}$ to >75 $m^3.tonne^{-1}$, the highest values being exceptional but when they arise are major emitters The IPCC factors do not differentiate between thermal and metallurgical coal mines. As coking coal mines tend to be gassy and of higher coal rank than thermal coals, a global value of 18 $m^3.tonne^{-1}$ is suggested for a whole mine emission estimator
- For DF(g), the proportion of drained gas, in a mine practicing methane drainage, can typically vary from 0.30 to 0.75 but a default value of 0.5 is should be used at this level. It should be noted that in low-gas mines, there may be no methane drainage.
- For coal production data, the companies should use total values for produced coal, as described in the SMP framework.

The calculations should be adjusted accordingly to the units used. To convert from volume flow to mass flow of methane, use a density of 0.000716 $t.m^{-3}$ at 0°C, 101.325kPa.

Due to the wide range of EF(g) that can arise depending on the geology, level 1 estimates are of little value for setting targets or determining mitigation policy.

SMP Level 1 reporting assumes that all drained coal mine methane is vented.

Level 2: Estimates of drained CMM flow

At SMP level 2, calculations follow the same principles as described for level 1, but with the use of country or regionally derived EFs for improved estimate on methane emissions. Any available whole mine drainage capture information could be used to help in the selection of an appropriate DF.

SMP level 2 is characterized by an increased granularity of the reported data, relative to level 1. This is achieved by reporting volumes of produced and marketed coal for all sites covered by the SMP framework and performing the calculation for all sites.

SMP Level 2 assumes all drained coal mine methane is subsequently vented.

Level 3: Spot measurements of drained CMM flow

The level 2 value can be refined by conducting spot manual measurements of drained gas flows from one or more mines.

Calculations

Drained methane flow = C(s)/100 x V(s) x A x T, $m^3.year^{-1}$

Where:
C(s) is the average methane concentration (%) in the drainage pipe at the venting location
V(s) is average gas mixture velocity ($m.s^{-1}$) in the pipe
A is the cross-sectional area (m^2) of the drainage pipe; a one-off measurement.
T is seconds in a year.

At SMP level 3, measured or estimated quantities of methane used and/or destroyed should be subtracted from the total drained methane to obtain the drained methane-vented.

Methodology

- Values for C(s) and V(s) can be obtained through weekly manual spot measurements, taken on the same working day of the week at a selected time that is normally during a production shift but continued during both holidays and any stoppages for safety, technical, or other reasons.
- Manual methane concentration measurements, C(s), can be made using a calibrated, portable instrument in which a gas sample is drawn past the detector. Values may also be taken from safety sensor network data, where available.
- Manual flow measurements of drained gas can be obtained using a pitot tube. Gas flow, V(s), is determined by multiplying the average velocity of the drained gas V(s) by the cross-sectional area of the pipe. Alternatively, flow can be derived by measuring the differential pressure across an orifice plate, while also recording the static pressure and pipe dimensions and a circular *Mear's* flow calculator used to determine the volume flow or mass flow of methane. Values may also be taken from safety sensor network data, where available
- Pressure and temperature measurements are needed to facilitate conversion of volumetric methane flow to mass flow (density of methane is 0.000716 $t.m^{-3}$ at $0^{o}C$, 101.325kPa).

It is encouraged that a C(s) and V(s) measurement frequency is chosen to give a rough representative estimate of the average values for these values over the reporting period.

Level 4: Continuous measurements of drained CMM flow

Site-specific, direct, continuous measurement is essential to obtain accurate and reliable emission data and is straightforward because the emissions are channeled to specific drainage venting locations. Level 4 involves the use of continuous emissions monitoring systems (CEMS), thus increasing the precision of the total methane volumes from a given source, replacing the level 3 estimation process.

Calculations

At this reporting level, calculations for volumes of methane drained should be performed automatically on a continuous basis, as specified in the methodology below. This reporting level also requires source-level data on temperature (T), pressure (P) and humidity (H) to adjust measured concentrations and volumes to standard conditions.

Similarly to SMP level 3 for this source, to calculate the drained coal mine methane-vented value, measured quantities of used and/or destroyed methane should be subtracted from the total measured, drained methane.

Methodology

- To obtain precise and accurate data, the measurement frequency for all parameters used in calculations (C(s), V(s), P(s), T(s)) should be in the range 1 - 10 minutes (UNECE, 2021) to enable continuous calculation of emitted volumes of methane.
- For concentration measurements, if a methane specific infra-red detector is used, care must be taken to employ a gas sampling system which removes excess moisture and gas-borne particles before introducing the gas to the instrument. This is because the high velocity gas in methane drainage pipework also carries moisture and dust particles. The value should be adjusted to percent of methane in moisture saturated air in post processing. To obtain flow rates, V(s), average velocity needs to be multiplied by cross-sectional area. There are various velocity measurement devices available. Common practice is to install an orifice plate in the drainage pipe and measure flow using differential pressure. It is important that orifice plates are inserted the correct way round and that the ratio of orifice diameter to pipe diameter is consistent with national standards (e.g., BS1042). Continuous flow measurement can be achieved using a differential pressure meter across an orifice plate, a V-cone, or by employing a vortex shedding or ultrasonic device. Instrumentation options and details are summarised in Appendix Table 5.2.
- Pressure and temperature measurements are used to facilitate conversion of volumetric methane flow to mass flow (density of methane is 0.000716 $t.m^{-3}$ at 0^oC, 101.325kPa).
- All electrical and electronic measurement equipment should be suitably rated

for use in accordance with the assessed gas hazard to which it is exposed and calibrated at a frequency as advised by the manufacturer.

- Details of the monitoring protocol should be recorded together with the types of instruments used, calibration details, frequency of measurement, measurement precision, and the period over which data has been collected. Data obtained by CEMS should be securely stored and backed-up. The measurement management process is summarised in Appendix Table 5.3.
- Uncertainty of the reported emissions should be calculated and the methodology used should be included in the submission.

A method for treating lost, corrupted, or out-of-range data should be specified and implemented. Results should be cumulated and reported to the International Methane Emissions Observatory (IMEO) annually by a prescribed date.

Calibration of instruments should be undertaken by suitably trained, competent staff under the supervision of a nominated senior manager who will also be responsible for data collection, processing, storage, and reporting.

Level 5: Reconciliation of independent measurements

This refers to reconciliation of the source-level mine measurements of methane vented at drainage stations and other SMP sources, as described in level 4 above, with top-down site-level measurements (such as ground-based, airborne, or spaceborne measurements of the methane concentrations in the atmosphere and the associated atmospheric modelling above, upwind, and/or downwind of the site). Top-down site-level emission estimates include all mine related methane emission sources except emissions from coal that has been transported elsewhere for export or for stockpiling at local coking plants.

The reconciliation process will be only applicable to sites emitting approximately 100 kg.h-1, or higher, based on level 4 monitoring methods in respect of current top-down detection levels. If performed according to principles described for this level, CEMS data at the mine level is considered to represent the highest quality source of Level 4 methane emission information and is thus invaluable for comparison with top-down site-level measurements.

The spatial-temporal resolution and time stamps of Level 4 and top-down site-level measurements should be recorded and a comparison between the latter and site-level data made over a common timescale where practical.

A Technical Guidance Document 'Uncertainty and Reconciliation' developed at a later stage will specify the principles of level 4 and level 5 data reconciliation processes and offer non-prescriptive guidance for operators to improve their methodologies if scientifically significant discrepancies are found. This may address potential questions such as resolving differences in granularity of measurements between top-down (quantifying the total of all site-level emissions) and level 4 (quantifying largest sources only).

4. Mitigation Options

Depending on the location, energy demand, gas purity and supply, drained methane can be used for power generation with or without heat recovery (co-generation), direct domestic or industrial thermal applications, chemical feedstock, or as a compressed or liquefied vehicle fuel (Appendix Table 5.4). Where utilisation is not feasible, drained methane can be destroyed by flaring. In any case, destruction by flaring is the lowest cost mitigation option. A fuller description of the options is provided in a UNECE publication (December 2016).

Power generation schemes would generally be designed to utilise a proportion portion of the variable drained gas flow to optimise power output. The surplus gas during peak drained flows should be vented or flared. Gas should also be vented or flared during stoppages and engine maintenance. Regularly serviced flames arrestors will prevent any risk of flame transmission into gas pipelines.

Drained methane concentration is a critical factor in determining mitigation potential and gas safety. A well-designed and managed gas drainage system should be able to deliver methane at concentrations of no less than 30% or higher to facilitate safe and efficient utilisation and mitigation.

References

CEC, Firedamp Drainage, Handbook for the Coalmining Industry in the European Community, Verlag Gluckauf GmbH, Essen 1980.

UNECE, Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines. ECE Energy Series No. 47. Second Edition, December 2016.

UNECE, Best Practice Guidance for Effective Management of Coal Mine Methane at National Level: Monitoring, Reporting, Verification and Mitigation. ECE Energy Series No. 71. Geneva 2021.

Appendices

Table 5.1 Summary of principal gas drainage methods

Method	Basic Technology
Underground pre-drainage	Directional long boreholes, in-seam along panel length
	Rotary-drilled boreholes across the panel
Surface pre-drainage	Vertical well with conventional fracture stimulation (gob wells subsequ
	Surface to in-seam well with multiple directionally-drilled laterals
Underground post-drainage	Cross-measure boreholes (from existing roadways)
	Drainage galleries
	Super-adjacent (or sub adjacent) boreholes
Surface post- drainage	Goaf wells

Adapted from UNECE, Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines. ECE Energy Series No. 47. Second Edition, December 2016. Table 7.1.

Table 5.2 Drained methane flow measurement

Parameter	Issues	Solution	Measurement technology	Calibration
Velocity in a pipe	Non-uniform distribution of flow. Aggressive environment due to humidity, dust, high air velocity	Determine a position factor to obtain the average velocity at the position of the transducer from industry references.	Differential pressure across an orifice plate or a V-cone (1). Vortex flow meter Ultrasonic measurement.	Accredited laboratory
Cross-section	Internal diameter may not be accurately known	Measure the internal diameter and calculate using geometry	Inside callipers	At installation
Methane concentration	Aggressive environment due to humidity, dust, high air velocity	Draw a sample of the gas though a hydrophobic filter before introducing it to the gas detector	For continuous measurement: a methane specific infra-red detector. For in situ calibration of methane detectors (level 4) or spot sampling of methane concentration (level 3), take test samples in bottles, pressurised tubes or proprietary bags for FID chromatography laboratory calibration checks.	Accredited laboratory

Note (1) V-cones offer advantages over the more commonly used orifice plates as they can be operated with very short upstream and downstream straight pipe lengths, with lower pressure loss.

Table 5.3 Managing resource measurements at Levels 4 & 5

Facility monitoring and reporting activities			Verification
Measurement	Frequency of measurements	Continuous (typically 1-10 minutes sampling rate) preferred where feasible	Check for consistency with the monitoring scheme
	Data processing	Data pre-processing and statistical analysis based on user specification	Check that the agreed data analysis protocols have been followed
		Out of range/failed state data treatment	
		Missing data treatment	
	Management of raw data	Remote transmission and storage	Ensure data backup and security is in place
		On-board storage	
	Installation and operation of measurement instrument	Position sensitivity	Inspect installation of measurement instruments
		All-weather proofing	
		Parameter sample conditioning	
		Parameter measurement frequency	
		Maintenance	
	Proper operation of the sensors	Calibration	Check calibration dates and certificates of sensor
		Accuracy	Ensure that the measurement system is compliant with any national standard, where they are established.
		Performance limits	
		Failure characteristics	
	Measurement of required variables	Monitor each required parameter	Ensure that the required parameters are monitored
Results	Calculations	Calculate and organise results to match required output specification	Check compliance with the monitoring methodology
		Combine relevant parameters to produce required output	Check formulae in the algorithm
	Documentation	Compile all data, supporting information, calculations and results in safe storage with backup for an agreed period of time	Facility for retrospective checks
Reporting	Record results in the established reporting system	Note any issues	Examine report for completeness and correctness (see Chapter 3.3)

Based on UNECE, Best Practice Guidance for Effective Management of Coal Mine Methane at National Level: Monitoring, Reporting, Verification and Mitigation. ECE Energy Series No. 71. Geneva 2021, Table 6.4.

Table 5.4 Comparison of CMM mitigation and uses

Use	Applications	Advantages	Disadvantages
Power generation	Gas-engine generators producing power for mine use or export to the grid	Proven technology; Waste heat recovery for heating mine buildings, miner's baths and shaft heating and cooling; Can yield carbon credits where markets exist	Interruptible and variable output – not liked by grid operators
High quality pipeline gas	Purified high quality CMM	Natural gas equivalent; Profitable where gas prices strong	Purification costly, only feasible for high quality pre-drained CMM (relatively stable flow required)
Medium quality pipeline gas	>30% methane for local residential, district heating and industrial use such as firing kilns	Low-cost fuel source	Distribution system and maintenance; Variable quality and supply; Costly gas holders needed to manage peak demands
Chemical feedstock	High quality gas for the manufacture of carbon black, formaldehyde, synthetic fuels and di-methyl ether (DME).	A use for stranded high quality CMM supplies	High processing cost (bid volumes and stable flow required); No CDM potential as carbon can be liberated
Mine site	Heating, cooking, boilers, coal fines drying, miner's residences	Displaces coal use; Clean, low-cost energy source	Demand seasonal
Vehicles	Purified high quality pre drained gas for CNG and LNG	Market access for stranded gas supplies; Can attract good prices	Processing, storage, handling and transport costs
Flaring (high destruction efficiency)	Destroy methane that is not used when utilisation plant goes off-line or where impractical to gather methane for utilisation	Lowest cost mitigation. Well designed, enclosed flares have high destruction efficiency	Portable pump-flare units may need additional fuel if CMM flow and quality is variable.

Adapted from UNECE, Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines. ECE Energy Series No. 47. Second Edition, December 2016. Table 6.1.