# Brief description of the source

Underground natural gas leaks are unintentional releases of natural gas to the atmosphere from underground pipes which can be caused by corrosion, material defects, joints and fitting defects or failures. While permeation from plastic pipes is not unexpected (it is a property of the material), it is included in this TGD.

Underground pipes are used to transport gas over long or short distances and can vary greatly in size and pressure, depending on the use and the volume of gas transported. Pipes can be made from a variety of material such as cast iron, cathodically protected and unprotected steel, black iron, copper, and plastic/polymer.

# Scope boundaries

Leaks and permeation from underground pipes to the atmosphere can occur at any point along an underground pipeline network, from wellhead to customer meter, including permeation from plastic pipes (which are considered herein). Unintended emissions from leaks or fugitive emissions are considered to be those detected through a robust above ground or internal pipeline detection survey. Methane emissions from above ground equipment (including below grade equipment such as in vaults or building basements which are physically accessible) are covered in the *Leaks TGD*.

Emissions resulting from incidents or third-party damages on underground and underwater pipelines are not considered herein. For guidance on determining emissions from incidents, third-party damages and equipment malfunctions, corrosion, where relevant, including large underwater leaks (blow-outs, third-party damage) that reach the atmosphere, please refer to the *Incidents and malfunctions TGD*.

Welded (i.e. which does not have any buried flanges) underground protected (e.g. cathodically protected) transmission pipelines, which can document/justify these conditions, are not considered herein.

Guidance on materiality is presented in the *General principles TGD*.

# Level 3 Quantification Methodologies

Level 3 quantification for fugitive emissions from underground pipes relies on activity data, typically the length and operating pressure of the pipelines, and emission factors considering the material of the pipes. Accepted source-specific emission factors, as defined in the *General Principles TGD*, (see examples below) or those prescribed by local regulation to the source level are considered as providing Level 3 estimates. Practitioners are encouraged to use emission factors that best represent conditions and practices at their facilities and adjust the factors, where warranted, to consider the differences between their systems and the reference system upon which the emission factor is based. Measurement of emissions from individual leaking components or plastic pipes may be considered but is not required at Level 3.

Some examples which may be used as references for emission factors are:

- Marcogaz, *Survey Methane Emissions for Gas Distribution in Europe,* 2017. Link
- EPA. *Greenhouse Gas Reporting Rule.* Title 40, Part 98 Subpart W-Petroleum and Natural Gas Systems. February 6, 2017. For distribution, Table W-7. Link
- Methane Emissions from the Natural Gas Industry, co-sponsored by the Gas Research Institute and EPA (June 1996); Volume 9 Underground Pipelines, Tables 9-1 Distribution, 9-3

Transmission, 8-3 Gathering and Processing, and 9-4 Production. Methane Emissions from the Natural Gas Industry, Volume 9: Underground Pipelines (epa.gov)
- Marcogaz, *Assessment of methane emissions from gas transmission and distribution operators,* 2019 https://www.marcogaz.org/wp-content/uploads/2021/04/WG_ME-485-Assessment-of-methane-emissions-for-gas-Transmission-and-Distribution-system-operator.pdf

Note: emission factors may include emissions both from leaks and incidents. Companies may adjust these values to separate emissions from leaks/permeation and incidents.

Activity data for underground pipes typically considers the length of the pipe or of the pipeline network. Activity data should be collected, in line with the selected emission factors (length of pipes of a certain material, thickness, pressure).

Fugitive emissions from underground pipes are the sum of emissions from each type of pipe.

# Level 4 Quantification Methodologies

Emissions from leaks and permeation from underground pipes can be quantified using different methodologies: direct measurement, measurement-based emission factors, engineering calculation, or a combination of the three. Other quantification methodologies could also be considered under the conditions presented in the *General Principles TGD*. Permeation is not practical to measure in the field because it is not possible to separate underground pipe connection leaks from permeation. Therefore, accepted calculations, as defined in the *General TGD*, are acceptable as Level 4 for permeation.[1] Emissions from natural gas leaks and permeation is the sum of the emission rate from all leaks and permeation through plastic pipes, adjusted to reflect the number of operating hours per year, where applicable.

## Direct measurement and Measurement-based Emission factors

Measurements or emission factors developed based on representative measured emissions are considered Level 4 emissions quantification.

To determine methane emissions from underground pipe fugitives, leaks first need to be identified. To do so, accepted detection technologies, as defined in the *General Principles TGD,* with a sufficient level of performance and accuracy, or detection equipment prescribed by local regulation can be used to identify the leak or a leaking segment of the pipe.[2] [3] [4] Following are some examples of detection technologies which can be used to detect leaks from underground gas pipes:

- Portable Flame Ionization Detector (FID)
- Combustible Gas Indicator (CGI)
- Vehicle-based measurement system (VMS)
- Laser detector

[1] For permeation specifically, Marcogaz, *Assessment of methane emissions from gas transmission and distribution operators*, section 6.4.1 and annex A and B, 2019 https://www.marcogaz.org/wp-content/uploads/2021/04/WG_ME-485-Assessment-of-methane-emissions-for-gas-Transmission-and-Distribution-system-operator.pdf

[2] More details on various detection equipment can be found at CCAC, *Conduction Emissions Surveys, Including Emission Detection and Quantification Equipment – Appendix A of the OGMP Technical Guidance Document,* 2017

[3] More details on Identification, Detection, Measurement and Quantification best practice can be found in Methane Guiding Principles, *Reducing Methane Emissions: Best practice guide - Equipment leaks,* 2019 https://methaneguidingprinciples.org/best-practice-guides/

[4] Methane Emissions from the Natural Gas Industry, Volume 9: Underground Pipelines (epa.gov), Section 6 Leak Rate Measurement Method.

If a leak is detected by the detection technology, it should be considered as a leak, in line with the scope boundaries defined above. The leak or emissions from pipe section may then be quantified, using an accepted quantification methodology[5], as defined in the *General Principles TGD*. Following are some examples of measurement techniques used to quantify leaks from underground pipes:

- High flow sampler, combined with a cover, to capture all leaks from a section of pipe (does not require identification of individual leaks)[6]
- Suction method[7]
- Cavity Ring-Down Spectroscopy

The measurement procedure, using, for example, measurement techniques described above, may entail selecting a suitable test site, followed by isolating the leaking or emitting segment and measuring the flow rate at normal operating pressure. [8] Soil gas diffusion and oxidation rate can also be considered when determining how much methane is ultimately emitted to the atmosphere.

Measurement-based emission factors, developed from a representative sample, can be applied on a population-basis, considering an average emission rate, the prevalence of leaks and the average time between the start of the leak and the repair.

The following formula can be used to develop emission factors for leaks from underground gas pipes:

$$EF_{Type} = L_{Type} * N_{Type} * D_{Type}$$

Where:

- $EF_{Type}$ = Methane emission factor per length unit of pipes of a certain type (for example, material, thickness or pressure)
- $L_{Type}$ = The average leak rate of leaks for pipes of a certain type
- $N_{Type}$ = The average number of leaks per length unit of pipes of a certain type
- $D_{Type}$ = The average duration of leaks from pipes of a certain type

Alternatively, the average total measured emissions per section of pipes of a certain type can be used to obtain an emission factor.

For plastic pipes, fugitive emissions from underground pipes are the sum of emissions from unintended leaks and from permeation.

## Sampling strategy for measurement-based emission factors

Level 4 emission factors should be based on measurements conducted on a representative sample. Pipeline type, environmental and operating conditions (e.g. material, thickness, age, pressure, frequency of leak surveys, soil characteristics) may be considered in determining 'like' systems that carry a common

[5] More details on Measurement on pipelines can be found at Marcogaz, *Assessment of methane emissions for gas Transmission and Distribution system operators – Annex F*, 2019
[6] Lamb, B. K. et al., *Direct Measurements Show Decreasing Methane Emissions from Natural Gas Local Distribution Systems in the United States,* March 2015
[7] GERG, *Methane Emission Estimation Method for the Gas Distribution Grid (MEEM),* 2018, https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwi-7Jbl9Lv2AhXsk4sKHV5VB2MQFnoECAgQAQ&url=https%3A%2F%2Fwww.gerg.eu%2Fwp-content%2Fuploads%2F2020%2F04%2FMEEM_Final_report.pdf&usg=AOvVaw1-mRO9Ur7x4xRHEaxF7EWp
[8] Lamb, B. K. et al., *Direct Measurements Show Decreasing Methane Emissions from Natural Gas Local Distribution Systems in the United States,* March 2015

emission factor. Each section of pipe that is not 'like' will require determination of a separate emission factor for that system based on the appropriate measurement studies. For guidelines on the methodology to develop a representative sample, please refer to the [*Uncertainty and reconciliation guidance*]. Detection frequency does not necessarily need to be aligned with measurement frequency. Over time, the emission factor should naturally adapt to shifts in repair practices.

When measurements are used to determine emission factors for 'like' systems, the emission factor may either be applied to all 'like' systems, independently of which systems the measurements have been performed on or the emission factor may be applied only to systems which have not undergone measurements. The first approach increases the uncertainty of emissions quantification at the level of individual facilities. Emission factors will tend to vary over time, as additional measurements are performed and integrated to calculate emission factors.

### Engineering calculation of fugitive emissions

Engineering calculations can be used to quantify methane emissions from distribution network leakage. For example, a method is to isolate a section, and measure the decline in pressure over time. If a section of distribution main, such as cast iron, is being replaced with upgrade material such as plastic, the cast iron section may be abandoned in place, and all service connections tightly sealed so that imposing pressure (e.g. with air) and measuring the decline in pressure relative to the volume of the isolated section, can determine very accurately the leakage from bell and spigot joints and corrosion.[9]

### Duration of fugitive emissions

As permeation is an intrinsic characteristic of plastic/polymer pipes, this type of fugitive emission is always present, and duration is not relevant, even though the rate of emissions might vary over time, due to changes in operating pressure.

Leaks, on the other hand, randomly occur throughout a gas pipeline network and it can be challenging to identify precisely what is leaking and when each one started to emit. Leak duration is necessary to establish emission factors per unit of pipeline length. Leak duration needs to consider the time between the occurrence and the repair of the leak. Duration of leaks from underground pipes can be treated similarly to the duration of other leaks. Examples of ways to account for the duration are presented in the *Leaks TGD*.

Times between occurrence and detection and between detection and repair can be considered to determine the average total time. Average leak duration can be determined based on a representative sample of 'like' systems.

## Engineering calculations for emissions from permeation of plastic pipes

Accepted engineering calculations, as defined in the *General TGD*, to quantify methane emissions from permeation of plastic pipes may be used for Level 4 quantification of this emission source. Partners are encouraged to determine the permeation coefficient through lab analysis/experiments and this coefficient should be specific to the characteristics of the type of plastic. The calculation should include elements of pressure and pipe characteristics. An example calculation which may be used to quantify emissions from permeation from plastic pipes can be found in:

- Verband Kunststoff-Rohre und -Rohrleitungsteile, *Richtlinie / Leitfaden für erdverlegte PE-Druckrohrleitungen in der Gas- und Wasserversorgung* – Section 3.7.4, 2017

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[9] New Measurement Data has Implications for Quantifying Natural Gas Losses from Cast Iron Distribution Mains | US EPA

$$V_g = P * \frac{\pi * ID * L * p * d}{t}$$

Where:

$V_g$ = Volume of gas emitted ($cm^3$ – normal temperature and pressure, i.e. 1 bar at 23˚C)

P = Permeation coefficient (e.g. For PE100 = 0.056) ($cm^3$ / m * bar * day)

ID = nominal internal diameter (mm)

L = length of pipeline (m)

p = Partial pressure of the gas in the pipe (bar)

d = duration (days)

t = nominal thickness of the pipe (mm)

It is important to note that potential emissions from leaks are not accounted for by the calculation presented above.