Brief description of source

The exploration for and extraction of oil and gas begins with well identification, drilling, and testing. Drilling is an operation necessary to construct wells of circular section applying excavation techniques and usually occurs during well exploration (wildcat and appraisal wells) and field development (development wells), as well as during the drilling of storage wells.

During the process, gas - especially from the drilling fluid (or "drilling mud") – can be vented directly to the atmosphere, routed to a flare[1,2] or used directly on site for heat and power generation.

The drilling fluid, with a solid phase and a liquid phase, can be a mixture of clay and other chemicals with oil (oil-based mud), synthetic (synthetic-based mud), and water (water-based mud[3]). It is used for several purposes such as maintaining desired pressure within the well, removing cuttings from the wellbore, cooling and lubricating/driving the drill bit. The gases entrained in the drilling mud are separated from the mud outside of the well bore in a mud separator (Shale shaker) and can be flared, used, or vented to the atmosphere, releasing methane (CH_4) and other pollutants. It is necessary to remove the gas to ensure appropriate mud quality before reuse. This operation is called mud degassing.[4]

System boundaries

Methane that is vented to atmosphere (continuously or periodically) from the mud separator train or the mud pit/container (where the mud is stored after degassing) are considered herein. Methane from the separator that is routed to sales, to flare or for on-site use, i.e., not vented, is not to be reported under the *Venting and purging* category.

Methane emissions from incomplete combustion of gas used for power or heat generation, should be reported under Incomplete combustion (see *Incomplete combustion TGD*). Methane emissions captured and routed to flare or thermal oxidation should be reported under Flaring (see *Flaring TGD*).

In the case of well exploration, if gas is unintentionally released from the wellhead (e.g. kick or blowout), it should be reported under Incidents (see *Incidents TGD*).

Level 3 Quantification Methodologies

Emission Factors

Accepted source-level emission factors or those prescribed by local regulation are considered as providing Level 3 estimates. Partners are encouraged to use emission factors that best represent conditions and practices at their facilities and adjust the factors or units, where warranted, to more accurately estimate emissions given differences between the reference system on which the emission factor is based, and their

[1] Standford university (2023) – *Drilling, completion and producing from oil and natural gas wells*. Retrieved from: Drilling, Completing, and Producing from Oil and Natural Gas Wells | Understand Energy Learning Hub (stanford.edu), on November 2023.

[2] MIST 2.0 adapted from Oil and Gas Portal – Introduction to oil and gas well drilling.

[3] Water-based mud: "a drilling fluid (mud) in which water or saltwater is the major liquid phase as well as the wetting (external) phase. General categories of water-base muds are fresh water, seawater, salt water, lime, potassium and silicate."
Energy Glossary (2023) – *Water-based mud*. Retrieved from: water-based mud | Energy Glossary (slb.com), on November 2023.

[4] MIST 2.0 adapted from Inventory of U.S. GHGs, EPA, 2019.

systems. Partners can estimate vented methane emissions along the mud separator train including mud degassing using the emission factors shown, as an example, in the Table below.

To quantify emissions, two data inputs are required:

- The type of drilling mud: water-based, oil-based, or synthetic-based mud
- The number of drilling days per spud. If not available, this number of days can be estimated and justified in the annual report. Offshore wells typically take considerably more days to drill.

The following emission factors apply to both oil and gas well.

Emission source	Methane Emission Factor	Source
Offshore well mud degassing ***(tCH$_4$/drilling day)***		
Water-based mud	0.2605	[1]
Oil-based mud	0.0586	[1]
Synthetic mud*	0.0586	[1]
Onshore well mud degassing ***(tCH$_4$/drilling day)***		
Water-based mud	0.0458	[1]
Oil-based mud	0.0103	[1]
Synthetic mud*	0.0103	[1]

*Nonaqueous drilling fluids. Substitutes for oil-based muds and occasionally used to replace water-based mud.
[1] API (2021) – *Compendium of greenhouse gas emissions methodologies for the natural gas and oil industry.* Retrieved from: 2021-api-ghg-compendium-110921.pdf, on November 2023. Adapted from EPA 1977[5]
[2] According to API, these values are likely conservative as it is expected that emissions typically predominantly occur when drilling through hydrocarbon bearing formations (Re: API Comments on EPA's Updates under Consideration for the 2021 GHGI: Mud Degassing and Produced Water Emissions (EPA memos, September 2020) https://www.epa.gov/sites/production/files/2020-10/documents/ghgi-webinar2020-degassing-comments.pdf)

Activity data

It is recommended that operating records are maintained to accurately represent well-drilling events, including, for example, the number of days of drilling, the type of mud used, or other relevant activity data required by the selected emission factor.

Level 4 Quantification Methodologies

Methane emissions from well drilling can be quantified using different methodologies: direct measurement, measurement-based emission factors or a combination of the two. Other quantification methodologies could also be considered under the conditions presented in the *General Principles TGD*.

As of early 2024, no specific quantification method suitable for L4 quantification has been established to quantify methane emissions from well drilling. Depending on the configuration of the drilling rig, it could be that methane is predominantly emitted from open systems, such as the shale shaker or mud pits, rather than closed pits, making it more challenging to measure. If sampling points are available, it could be further

[5] U.S. EPA, 1977. Atmospheric Emissions from Offshore Oil and Gas Development and Production. Office of Air Quality Planning and Standards, Research Triangle Park, NC. PB272268.

investigated if mud sampling in appropriate conditions followed by laboratory analysis could constitute a quantification method for methane emissions, aligned with L4 requirements.

Some mud logging systems could include information on the methane content of the mud before degassing, using measured data from chromatographs. Provided the data relies on source-specific measured parameters and that it can be demonstrated that the system provides methane emissions estimates with a sufficient level of certainty, mud logging systems can be used to quantify methane emissions from well drilling at Level 4, or be used to help obtain an Emission factor derived from these measurements.

Furthermore, no engineering calculations or process simulation providing L4 quantification estimates have been identified. However, if sufficiently robust methodologies have been developed and are made available, these could constitute L4 quantification methodologies.

Direct measurement and Measurement-based Emission factors

Measurements (including continuous and periodic monitoring) or emission factors developed based on representative measured emissions are considered Level 4 emissions quantification. Measurements must be taken that represent the total flow of each gas stream that is vented to the atmosphere.

Level 4 emission factors should be based on measurements conducted on a representative sample. For guidelines on the methodology to develop a statistically representative sample, please refer to the Uncertainty TGD.

The general principal to level 4 quantification of methane emissions from vents is to quantify:

- Gas flow
- Methane content
- Duration of the event (purge, vent, blowdown, flare…)

Methane emissions from gas venting are the multiplication of these three elements. These three elements can be quantified using the equipment and techniques described in the *Purging and venting TGD* for direct measurements and measurement-based emission factors.