Brief description of source

The life cycle of an oil or gas well can be divided into several phases and events. Such phases can be briefly described as (1) Planning, (2) Drilling, (3) Completion, (4) Production, and (5) Abandonment[1]. This TGD will focus mainly on the well events that happen after the drilling phase is completed and are not included in other TGDs.

Well completion refers to the procedure of making an oil or natural gas well for production following the initial drilling or 'workover'. The process includes several steps such as removing the drill string, lowering the casing, cementing the casing in place, performing the perforations in the zone of interest, and performing well stimulation in the reservoir to boost production. Well stimulation can include non-hydraulic fracturing completions, such as acid injection (acidizing), or hydraulically fracturing the reservoir. It also involves the expulsion of drilling and fracturing fluids and the installation of the production valve. In cases where hydraulic fracturing is used to stimulate production, the expulsion of 'frac' fluids from the reservoir could lead to high levels of methane emissions if these are not properly captured or flared off[2].

Completion of new wells and reworking of existing wells in tight formations may involve hydraulic fracturing of the reservoir to increase well productivity. Hydraulic fracturing involves fracturing the reservoir rock with very high-pressure water containing a proppant (usually sand). This keeps the fractured surfaces 'propped open' after the water pressure has been reduced. At the end of the process, the excess water and proppant are removed. This well-cleanup process may result in significant releases of methane into the atmosphere.

Completing hydraulically fractured wells involves producing the fluids at a high rate to lift the water and excess sand to the surface and clear the well bore and formation to initiate oil and gas flow. Typically, the gas-liquid separator installed for normal well flow is not designed for these high liquid flow rates and three-phase (gas, liquid, and sand) flow. Therefore, a common practice for this initial well completion has been to redirect the recovered fluids to a pit or tanks where water, hydrocarbon liquids, and sand are captured, and slugs of gas vented to the atmosphere or flared. Completions can take anywhere from several hours for oil wells to several weeks for gas wells, during which time a substantial amount of gas may be released to the atmosphere, flared or captured and sent to the pipeline. Production levels are tested during the well completion process, and it may be necessary to repeat the fracture process to achieve desired production levels from a particular well.

A common practice in North America, required by US EPA regulations[3] for hydraulically fractured oil and gas wells is to route completion flowback to "reduced emissions completion" (REC) equipment. This equipment includes a purpose designed sand separator and over-sized gas/liquid separator which captures gas of a quality that can be sent to a sales pipeline. Initial flowback, especially where inert gases such as carbon dioxide or nitrogen are injected with the fracture water (energized frack) may be unsuitable for injecting into the sales line and is normally tested and vented until it meets the desired pipeline quality.

For well completions that do not involve hydraulic fracturing, the duration of the flowback period, also referred to as well cleanup, is generally shorter. Consequently, the quantity of methane (CH4) released is usually less compared to well completions with hydraulic fracturing. The process may include flaring or venting of the produced gas into the atmosphere[4].

[1] Well integrity lifecycle - PetroWiki (spe.org)
[2] Well Completions and Workovers | US EPA
[3] Oil and Gas New Source Performance Standards for Hydraulically fractured well completions: https://www.epa.gov/sites/default/files/2016-09/documents/sources_covered_2012nsps.pdf
[4] 2021-api-ghg-compendium-110921.pdf

System boundaries

Methane that is vented to the atmosphere (continuously or periodically) from the process of well completion of both oil and gas wells, which emanate from a pit or tank (where the recovered fluids and solids are temporarily stored) are considered herein. For hydraulic fracturing, this also includes initial flowback using REC, during completion of wells.

Quantification of methane emissions from well drilling is described in the *Well drilling TGD.* Quantification of methane emissions from other well events such as well testing, workover and well interventions, and plugging and abandonment are covered in the *Well events TGD*.
Natural gas routed to sales, reinjected into the reservoir, or for on-site use, i.e. not vented, are not to be reported. Methane emissions captured and routed to flare or thermal oxidation should be reported under Flaring (see Flaring TGD).

If methane is unintentionally released as part of the well completion process due to an unexpected event, it should be reported under Incidents (see *Incidents TGD*).

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

Level 3 Quantification Methodologies

Emission Factors

Accepted source-level emission factors, as defined in the *General Principles TGD*, or those prescribed by local regulation are considered as providing Level 3 estimates, provided they are specific for the source type and based on throughput of product from the well. Partners are encouraged to use emission factors that best represent conditions and practices at their facilities and adjust the factors, where warranted, to more accurately estimate emissions given differences between the reference system on which the emission factor is based, and their systems.

The following tables present examples of emission factors which can be used to estimate methane emissions from well completion.

Source	Methane Emission Factor (tonnes CH4/completion)	Whole Gas Emission Factor (scf gas/completion)
Gas Well Completions with Hydraulic Fracturing: Uncontrolled Venting[6]	28.8	1,842,577
Gas Well Completions with Hydraulic Fracturing: REC with Venting[6]	13.5	866,413
Oil Well Completions with Hydraulic Fracturing: Uncontrolled Venting[6]	14.4	922,498

Oil Well Completions with Hydraulic Fracturing: REC with Venting[6]	0.6	39,357
Gas Well Completions without Hydraulic Fracturing: Vented[7]	1.74	111,173
Oil Well Completions without Hydraulic Fracturing: Vented[7]	0.014	902
Offshore gas well completion[8]	136.2[5] (kg CH4/completion-day)	8,700,000

Reference: Table 6-5. Well completion Methane Emission Factors for oil wells[6], Table 6-6. Well completion Methane Emission Factors for Onshore Well Completions without Hydraulic Fracturing for oil and gas exploration[7] and Table 6-7. Offshore Well Completion Methane Emission Factors for Oil and Gas Exploration[8]

Level 4 Quantification Methodologies

There are no methods to quantify emissions from gas well hydraulic fracturing with flow routed to an open pit at Level 4. These emissions can neither be measured nor quantified using engineering calculations and are to be quantified at Level 3.

Direct measurement and Measurement-based Emission factor

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. System configurations, environmental and operating conditions (e.g. reservoir geology, oil or gas reservoir, pressure, horizontal or vertical drilling aspect, etc) should be considered in determining 'like' systems that carry common emission factors. Each system that is not 'like' will require determination of a separate value for that system, based on the appropriate measurement studies. For guidelines on the methodology to develop a statistically representative sample, please refer to the *Uncertainty TGD*.

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 principle to level 4 quantification of methane emissions from well completion venting is to quantify:

- Gas flow

[5] Methane content assumed 81.6 mole% as per API Compendium.
[6] REC with Venting refers to venting during the initial flow back period, followed by recovery of the gas after a sufficient volume of gas is available to enable separation 2021-api-ghg-compendium-110921.pdf
[7] 2021-api-ghg-compendium-110921.pdf
[8] 2021-api-ghg-compendium-110921.pdf

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

Methane emissions from well completion venting is 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.

Engineering calculations

Since the flow rate is not consistent throughout the duration of the completion flowback, Partners can calculate the total flow volume from the recorded flowback rates and use the equation below to quantify emissions at level 4.

Some examples of such calculations can be found at:

- For well completion with hydraulic fracturing : US EPA, Subpart W – Petroleum and Natural Gas Systems, Eq. W – 10A, Eq. W – 10B https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-W
- For gas well completion without hydraulic fracturing : US EPA, Subpart W – Petroleum and Natural Gas Systems, Eq. W – 10A, Eq. W – 10B https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-98/subpart-W

In the case where the flowback process is not continuous, Partners could add all the recorded flowback volumes to determine the overall flowback volume, deducting any amount of CO_2 or N_2 injected into the reservoir during the energized fracture job. This calculation methodology is shown in the following equation[9].

$$E_{s,n} = [FV_{s,p} - EnF_{s,p}]$$

$E_{s,n}$ = Annual volumetric total gas emissions in cubic feet at standard conditions from gas well venting during completions or workovers following hydraulic fracturing for a well.

$FV_{s,p}$ = Sum of all flow volumes measured from the well (cubic feet)

$EnF_{s,p}$ = Volume of N_2 injected gas in cubic feet at standard conditions that was injected into the reservoir during an energized fracture job for the well. If the fracture process did not inject gas into the reservoir or the injected gas is CO_2, then $EnF_{s,p}$ is 0.

[9] CCAC, Technical Guidance Document Number 8: Well venting/Flaring during well completion for hydraulically fractured gas wells, 2017