# *Annex H – $CH_4$ emissions analysis and scenarios*

There have been numerous studies on methane emissions during the past 10 years, focused both on the measurement as well as quantifying global $CH_4$ emissions[1]. However, these studies neither characterize emissions in a way that allows for the application of a benchmark methodology (e.g. $CH_4$ emissions/energy produced) and nor distinguish between upstream, midstream and downstream emissions.

For that purpose, we have looked into the 2019 USA National Inventory Report (NIR, respecting to 2017 data), in particular to the Common Reporting Framework tables, to understand how USA $CH_4$ connected with oil & gas value chain would be distributed between the different oil & gas segments. This data is reported in Table1.B.2, which is copied below for reference.

| **GREENHOUSE GAS SOURCE AND SINK CATEGORIES** | **ACTIVITY DATA(1)** | | | **IMPLIED EMISSION FACTORS** | | | **EMISSIONS** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Description(1)** | **Unit(1)** | **Value** | **$CO_2$(2)** | **$CH_4$** | **$N_2O$** | **$CO_2$** | | **$CH_4$ (4)** | **$N_2O$** |
| | | | | | | | **Emissions(3)** | **Amount captured** | | |
| | | | | ***(kg/unit)* (5)** | | | **(kt)** | | | |
| **1. B. 2. a. Oil(6)** | | | | | | | 23341.04 | NA | 1730.66 | 0.04 |
| 1. Exploration | Annual Domestic Production | 10^6 Bbl(oil US) | 3414.58 | 485243.70 | 4198.02 | 0.74 | 1656.90 | NA | 14.33 | 0.00 |
| 2. Production(7) | Annual Domestic Production | 10^6 Bbl(oil US) | 3414.58 | 5257036.02 | 426386.77 | | 17950.54 | NA | 1455.93 | |
| 3. Transport | Refinery Feed | 10^6 Bbl(oil US) | 6055.24 | 179.61 | 1263.29 | | 1.09 | NA | 7.65 | |
| 4. Refining/storage | Refinery Feed | 10^6 Bbl(oil US) | 6055.24 | 615657.44 | 4679.15 | 6.01 | 3727.95 | NA | 28.33 | 0.04 |
| 5. Distribution of oil products | Distribution | NA | NE | NE,NA | NE | | NE | NA | NE | |
| 6. Other | Abandoned Wells | abandoned wells | 2598505.86 | 1.75 | 86.36 | | 4.55 | NA | 224.42 | |
| **1. B. 2. b. Natural gas** | | | | | | | 26329.07 | NA | 6676.99 | |
| 1. Exploration | Annual Production | 10^9 ft^30 | 27.29 | 17698963.55 | 1812155.80 | | 483.02 | NA | 49.46 | |
| 2. Production(7) | Annual Production | 10^9 ft^3 | 27.29 | 104254931.66 | 158902225.70 | | 2845.22 | NA | 4336.60 | |
| 3. Processing | Annual Production | 10^9 ft^30 | 27.29 | 822673044.08 | 17171591.48 | | 22451.57 | NA | 468.63 | |
| 4. Transmission and storage | Consumption | 10^9 ft^3 | 27.11 | 19659020.70 | 47758172.14 | | 532.96 | NA | 1294.72 | |
| 5. Distribution | Consumption | 10^9 ft^3 | 27.11 | 515420.20 | 17505544.40 | | 13.97 | NA | 474.58 | |
| 6. Other | Abandoned Wells | abandoned wells | 559411.14 | 4.15 | 94.74 | | 2.32 | NA | 53.00 | |

1 See for example the Environmental Defense Fund publication "Methane Research: The 16 Study Series"

In the USA NIR the emissions from Flaring and Venting are included within the different categories 1.B.2.a Oil and 1.B.2.a Gas. From this table, it is relatively straightforward to produce a partition of $CH_4$ emissions between Upstream, Midstream and downstream, for both Oil and Gas.

| **Oil** | **Categories** | **CH4 emissions (kt)** | **%** |
|---|---|---|---|
| Upstream | Exploration + production + other (abandoned Wells) | 14.33 + 1455.93 +224.42 = 1694.68 | 98 |
| Midstream | Transport + Refining/storage | 7.65 + 28.33 = 35.98 | 2 |
| Downstream | Distribution of oil products | - | |
| **Gas** | **Categories** | **CH4 (kt)** | **%** |
| Upstream | Exploration + production + other (abandoned Wells) | 49.46 + 4336.60+53.00 = 4439.06 | 66% |
| Midstream | Processing + Transmission and storage | 468.63 +1294.72=1763.35 | 26% |
| Downstream | Distribution | 474.58 | 7% |

## $CH_4$ scenarios

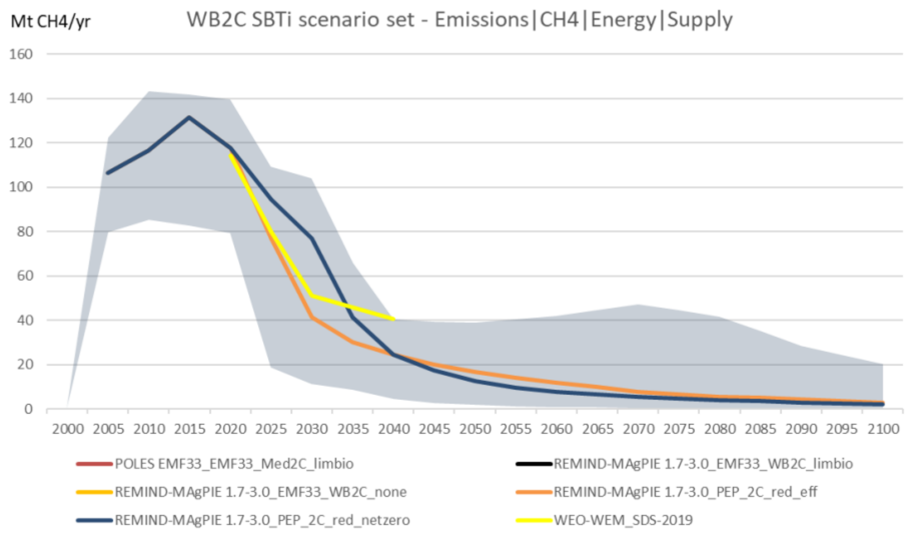
From the scenario set presented in Annex C only four have information on $CH_4$ for the energy supply side and they are:

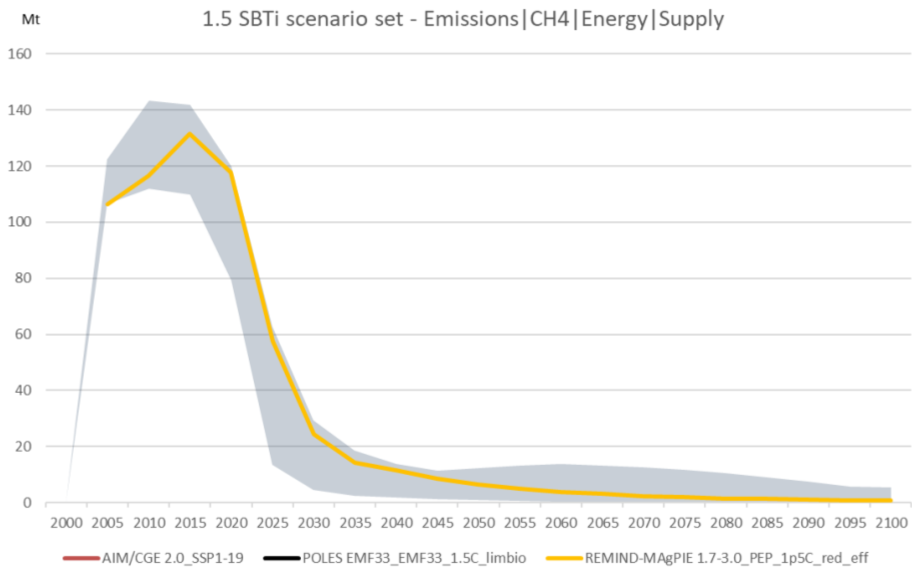
- WB2C: REMIND-MAgPIE 1.7-3.0_PEP_2C_red_eff; REMIND-MAgPIE 1.7-3.0_PEP_2C_red_netzero and WEO-WEM_SDS-2019;
- 1,5C: REMIND-MAgPIE 1.7-3.0_PEP_1p5_red_eff.

For scenarios in the IPCC database, according to the variables description, $CH_4$ emissions go well beyond emissions from oil production and refining, and include “$CH_4$ emissions from fuel combustion and fugitive emissions from fuels: electricity and heat production and distribution (IPCC category 1A1a), other energy conversions (e.g. refineries, synfuel production, solid fuel processing, IPCC category 1Ab, 1Ac), incl. pipeline transportation (IPCC category 1A3ei), fugitive emissions from fuels (IPCC category 1B)[2] and emissions from carbon dioxide transport and storage

2 This includes all fugitive emissions from fuels, including coal, oil and gas.

(IPCC category 1C) (Mt CH4/yr)". Only the IEA WEO 2019 (IEA, 2019), explicitly includes $CH_4$ emissions from oil and gas operations (see below pictures).




However, both the present levels of $CH_4$ emissions (~120 Mt $CH_4$/year), as well as the reductions advanced in the scenarios, are quite similar, which raises the question if the variables in the IAM database are appropriately described or if the IEA emissions are overestimated. Given recent studies on methane that raise the issue that $CH_4$ emissions are likely to have been seriously underestimated for decades (Schwietzke *et al.*, 2016; Hmiel *et al.*¸2020), we have taken the approach that the IEA data is the most accurate approximation to $CH_4$ emissions of Oil & Gas Upstream and Midstream segments and that the IAM $CH_4$ scenarios can also be taken as Oil & Gas $CH_4$ scenarios only. The reduction levels advanced in any of the scenarios are, in all cases, commensurate with other initiatives proposing $CH_4$ reductions, namely the Climate & Clean Air Coalition (CCAC) 45% reduction by 2025 and 75% by 2030.

In principle, these curves can be used to compute a kg$CH_4$/TJ of primary energy supplied, leading to a Scope1, $CH_4$ emissions intensity pathway. Using available data from the IEA WEO 2018 (IEA, 2018) on the GHG intensity of Oil and Gas, a global average carbon intensity due to methane emissions for oil (32.64 kg$CO_2$e/boe) and gas (60.9 kg$CO_2$e/boe) can be established.

Assuming that emissions contract according to the abatement potentials, it can be established a curve for the $CH_4$ emission intensity of Upstream oil and gas. This simplified approach, allows the application of the SDA and the recognition of differentiated starting positions from companies on important mitigation of upstream methane reductions.

## References

IEA (2018), World Energy Outlook 2018, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2018

IEA (2019), World Energy Outlook 2019, IEA, Paris https://www.iea.org/reports/world-energy-outlook-2019

Hmiel, B., Petrenko, V.V., Dyonisius, M.N. et al. Preindustrial 14CH4 indicates greater anthropogenic fossil CH4 emissions. Nature 578, 409–412 (2020). https://doi.org/10.1038/s41586-020-1991-8

Schwietzke, S., Sherwood, O., Bruhwiler, L. et al. Upward revision of global fossil fuel methane emissions based on isotope database. Nature 538, 88–91 (2016). https://doi.org/10.1038/nature19797