METHANE EMISSIONS FROM GLOBAL NATURAL GAS SUPPLY CHAINS

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Overview

The accurate quantification of methane emissions is an increasingly important topic as climate targets become more stringent. Methane is the second most critical greenhouse gas (GHG) and is estimated to have caused 25% of anthropogenic global warming seen today (EDF, 2019). Since 2017, countries have pledged to be net-zero by 2050/60 and a number of these have introduced methane strategies to curb their emissions of this potent GHG (EDF, 2020, European Commission, 2020, GMI, 2020, Hausfather, 2020, Xu et al., 2020). Globally, in accordance with the Paris Agreement, nations are obligated to account for their GHG emissions, but estimates are often based on uncertain default emission factors, rather than direct measurements. There have been many efforts put into quantifying methane emissions in the oil and gas sector (upstream, midstream and downstream) in the literature, but these have largely focused on measuring emissions from specific facilities, emissions within country or state/region boundaries or do not consider emissions across an entire supply chains (Allen et al., 2013, Brandt et al., 2016, IEA, 2020, thinkstep, 2017, Zavala-Araiza et al., 2018). These studies, while providing valuable information, only estimate emissions from one section (or subsection) of the gas supply chain, or do not compare emissions across multiple supply chains and thus, it is currently uncertain how emissions and emission intensities vary between gas supply chains within a given country or how certain emission data are.

These are the aims and novelties of this work- to estimate the emissions and emission intensity of gas supply chains; assess the reliability of the underlying data and determine whether there are any regions in the world at risk of high emissions. Our results can be used to identify key emission reduction requirements, as well as highlighting key areas where better data is urgently needed.

Methods

In this work, we consider the world's largest supply chains, accounting for 65% of consumption and LNG trade, 72% production and 77% pipeline trade. All supply chains are considered: domestic production, exports (pipeline and liquefied natural gas (LNG)), imports (pipeline and LNG) and domestic consumption. We focus on the 17 countries which make up the world's largest gas producers and consumers and countries which import/export gas to these countries are also considered. In total, 80 countries and 252 supply chains are considered.

To estimate methane emissions across a supply chain, the gas throughput and emission factor data are needed. The gas throughput is the volume of natural gas passing through a stage in the gas supply chain (Figure 1). This is calculated using gas production and consumption data, which was collected from the literature, mainly from BP and IGU (BP, 2019, IGU, 2018) along with gas loss data (gas used within a stage to fuel processes and activities). Therefore, the gas throughput is not constant across the whole supply chain and decreases moving downstream. The methane emissions are then calculated by applying an emission factor. The emission factor data collected is mostly from national greenhouse gas inventories submitted to the United Nations Framework Convention on Climate Change (UNFCCC) (UNFCCC, 2019), with data from thinkstep, MARCOGAZ and Tokyo Gas to fill in any data gaps. (MARCOGAZ, 2017, MARCOGAZ, 2018, thinkstep, 2017, Tokyo Gas, 2018) This allowed the quantity of methane emitted per stage to be calculated. The emissions intensity is then calculated by dividing the quantity of methane emitted per stage by either the quantity of gas produced or consumed i.e. throughput in the production or distribution stages, respectively. These can then be summed up across the supply chain to derive and emissions intensity for the supply chain. Data from 2017 was used because at the time of writing, it is the most recent inventory submitted to the UNFCCC.

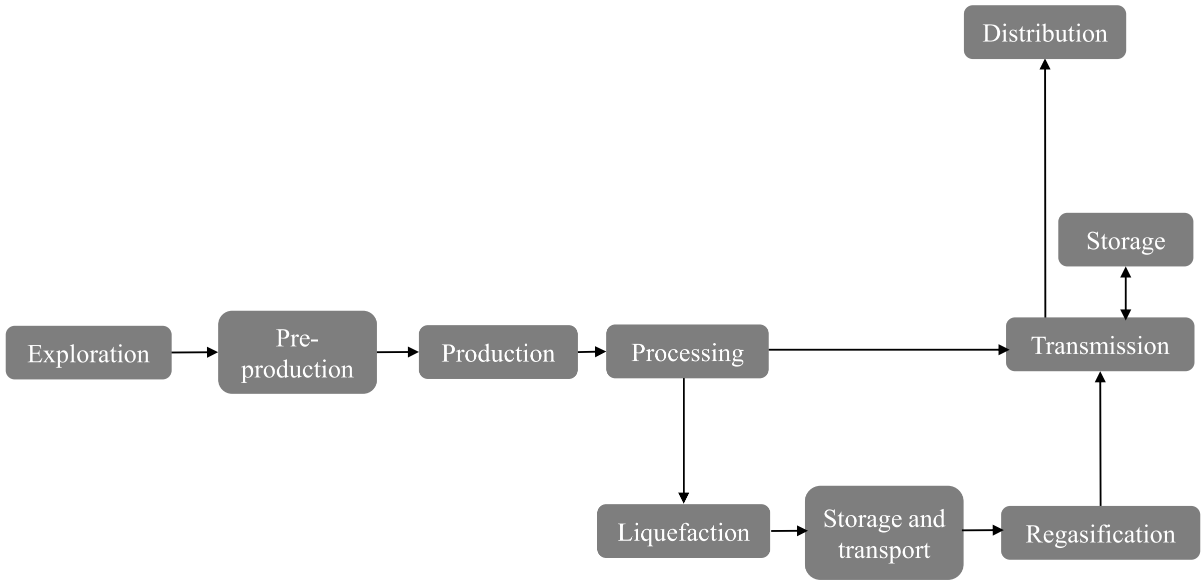

Figure 1: Flow diagram stage in the gas supply chain, from upstream (production and processing), midstream (LNG transport) and downstream (distribution).

The uncertainty in the emissions data is estimated using bootstrapping resampling and a risk matrix was developed to identify regions at risk of high emissions. The emissions data collected from the UNFCCC submissions was estimated using one or a combination of methods: Tier 1 (generic emission factors), Tier 2 (region or country specific emission factors) or Tier 3 (country specific). The uncertainty in the emissions data was assessed by resampling the emission factor data set as is and without the Tier 1 data. This was carried out in MATLAB and 400 new emissions datasets were generated for our 252 supply chains. This was conducted for the stages in which emissions data was collected from UNFCCC submissions: production, processing, transmission and storage and distribution.

A risk assessment was developed to quantify the risk of high emissions for the 80 countries considered in this work. Risk is the product of consequence and likelihood, where consequence is the emissions rate relative to a benchmark and likelihood is the accuracy of the emissions reporting method. The benchmark emissions rate we use is the Oil and Gas climate Initiatives target of 0.2%. Likelihood is based on the tier, with Tier 1 assumed high likelihood of inaccurate emissions reporting and Tier 3 low likelihood of inaccurate emissions reporting.

Results

We estimate 26.4 Mt CH_4 was emitted by these supply chains in 2017: 15.5 Mt CH_4 from production and processing, 7.8 Mt CH_4 from T&S and distribution and 3.1 Mt CH_4 from trade. The average emissions per supply chain is 28 kt CH_4 but there is a wide variation across supply chains (Figure 2). The average emissions intensity is 0.7% and intensities ranges from 0.01% to 8.1%. USA domestic production is the supply chain with the largest emissions (kt CH_4), followed by Russian domestic consumption, but when comparing emissions intensity with kt CH_4 emitted by each supply chain, there is no correlation. When examining these two supply chains, they are the largest supply chains in regard to natural gas throughput, which resulted in large quantities of methane being emitted despite having median emission intensity. Similarly, supply chains which have high emission intensities have low(er) emissions when the gas throughput is low. The supply chains with the higher emissions intensities are those which use Tier 1 methods to estimate their emissions.

The majority (72%) of the data collected for this work are Tier 1 and are typically used by Non-Annex-1 countries in the absence of primary data. Annex-1 countries also use Tier 1 emission factors as placeholder data where primary data is unavailable, but Tier 3 and 2 emission factors are more commonly applied. When comparing tiers, Tier 1 emission factors can be up to 6.6-times higher than Tier 2 and 3 and the uncertainty bounds are much higher; ±20% to ±500% uncertainty for Tier 1 compared to ±5.2% to ±276% for Tier 2 and 3 (IPCC, 2003, IPCC, 2006). The impact of the high dependency on Tier 1 emission factors was assessed through bootstrapping resampling. When the emissions data was resampled omitting Tier 1 data, both the range and average emission factor decrease significantly and when emissions were recalculated, emissions are 4.1 Mt CH_4 from both production and processing and T&S and distribution; a 3.8-fold decrease in upstream emissions and 47% reduction in downstream emissions compared to the original estimates. This suggest that the emissions estimated using the data reported in national GHG inventories could be an overestimate because of the high reliance on Tier 1 emission factors. It also suggests that countries which rely solely on Tier 1 emission factors are at risk of inaccurate emission estimates. When the risk of high emissions is considered, it appears that countries which reply on Tier 1 emission factors are also at risk of high emissions. In total, 58% of countries are at high risk of high emissions in production and 40% at high risk of emissions in distribution. No countries are at high risk of high emissions in processing and distribution, but 56% and 43% of countries, respectively, are at moderate risk. However, the results of the risk assessment are dependent on the assumption that Tier 2/3 emission factor data are accurate.

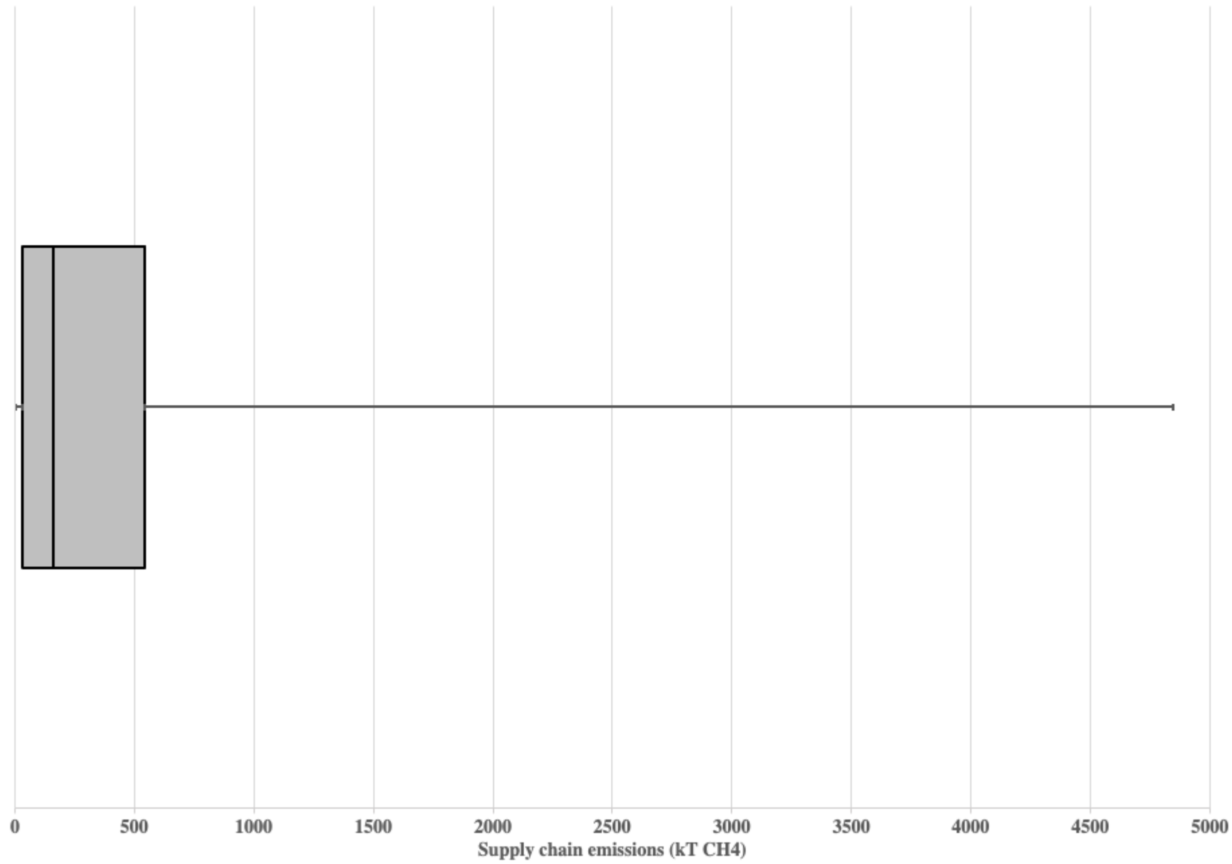

Figure 2: Methane (kt CH_4) emitted across supply chains.

Overall, there is a high degree of uncertainty in emission estimates. While the results of the bootstrapping resampling suggest that the Tier 1 emission factors could be resulting in an overestimate of emissions, the results of the risk assessment suggest a high percentage of countries could also be at risk of high emissions. We are unable to determine whether our emission estimates are an overestimate or an underestimate as we cannot determine how representative the Tier 1 data is for the countries that use it. However, it is clear that there is a high level of uncertainty in emission estimates, as a result of the large number of data gaps in emissions reporting. To reduce this uncertainty, more primary data is needed to reduce the reliance on Tier 1 emission factors.

Conclusions

We estimate 26.4 Mt CH_4 to have been emitted in 2017 by all 252 supply chains considered. 15.5 Mt CH_4 was emitted from upstream production and processing, 7.8 Mt CH_4 from downstream T&S and distribution and 3.1 Mt CH_4 from trade (pipeline transport and LNG liquefaction, shipping and regasification). The average emissions emitted by a supply chain is 28 kt CH_4 but there is a large variation, ranging from >1,000 kt CH_4 to <0.1 kt CH_4. The emissions intensity also varies but the majority have lower emissions. Both a high emissions intensity and large gas throughput result in large emissions and we found no correlation between emissions and emissions intensity, which suggests that poor emissions management cannot be attributed to either independently. Our results also showed high uncertainty in emission estimates and that a large proportion of the countries assessed are at high risk of (unaccounted) high emissions. When assessing the emissions data, resampling the data omitting the Tier 1 data we found that supply chain emissions decreased by 3.8-fold upstream and 47% downstream. This suggests that emissions estimated using Tier 1 data could be an overestimate and any country which solely relies on this data is at risk of inaccurate emission estimates. However, the risk assessment indicated a significant proportion of countries to be at high risk of high emissions. We were unable to deduce whether our emissions estimates are an over or underestimate, as we were unable to determine how representative or accurate Tier 1 data is to the countries which use it.

Overall, the findings of this work suggest the largest gas supply chains are significant sources of methane. However, there is a high degree of uncertainty in the estimates, primarily related to the high dependence on Tier 1 emission factor data. Despite this, large quantities of methane are emitted by gas supply chains. More efforts should be put into collecting emissions data and improve the transparency in reporting to increase the certainty in emission estimates. These would aid in better emission accounting and allow for effective emission abatement strategies to be developed.

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