Estimating greenhouse gas emission level of a natural gas transmission pipeline from point A to B in West Java based on INGAA and IPCC guidelines

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Abstract. When being transported by pipeline, natural gas is often emitted to the atmosphere, either for depressurization (venting emissions) or leak through the pipeline (fugitive emission). The emission level must be well estimated to provide relevant informations and recommendation to formulate strategies for reducing greenhouse gas (GHG) emission. Organizations such as INGAA (The Interstate Natural Gas Association of America) and IPCC (Intergovernmental Panel on Climate Change) provide GHG estimation guidelines which are adopted by many companies and countries. This study estimates the emission level of a natural gas pipeline in West Java using emission factors referring to INGAA and IPCC guidelines with flow rate variation. The result shows that the flow rate variation affects the total emission based on Tier 2 and Tier 3 INGAA as well as Tier 1 IPCC. It is also shown that fugitive emissions dominate the total emission of gas pipeline. However, the use of different methodologies and guidelines gives different emission level for the same pipeline. Different estimation results of emission level have been reviewed and national emission factors database for gas transmission is highly suggested to be developed.

1. Introduction
The “greenhouse effect” is the phenomenon where atmospheric gases absorb and trap the terrestrial radiation leaving the Earth’s surface, causing a warming effect on earth [1]. Gases that trap heat in the atmosphere are called greenhouse gases (GHG). For emissions from oil and natural gas systems, CO₂, methane, and nitrous oxide are the main emissions released from combustion sources and natural gas processes [1]. The use of fossil fuel contributes in environmental problems due to their emission levels. However, natural gas can be considered as clear energy because it has lower emission level than other fossil fuel such as coal and petroleum. The low level of GHG emission of natural gas has become one of considerations of Indonesian Government in setting the target to optimize the consumption of natural gas in domestic market.

In Indonesia, the transportation of natural gas in Indonesia is still dominated by pipeline, both transmission and distribution pipeline networks. Although, natural gas is environmentally friendly fuel and cheaper than other fossil fuels but it still has risk to release GHG emission during the transporation process through pipeline. Methane, the main component of natural gas, is a more potent GHG gas than CO₂ as methane produces 21 times of trapped heat in the atmosphere when compared to CO₂ [2].
Several methane emissions studies have been reported as direct measurements from different natural gas supply chain facilities (exploration, production, gathering, processing, transmission, and distribution) with a variety of CH4 emission sources including fugitive, venting, and combustion emissions for objects in United States [3,4,5]. These studies basically estimate and calculate new emission factors based on direct measurements and mostly refer to The Environmental Protection Agency (EPA) Greenhouse Gas Inventory (GHGI) in comparing their calculation results. The other study in Russia was also done for Russia long distance gas transmission pipeline [6]. It was initiated by assessing 5 gas compression stations through direct sampling. The assessment result was then developed to extrapolate emission factors of Russian long distance gas transmission pipeline. However, these studies [3,4,5,6] had not assessed the variation of natural gas throughput and its contribution to emissions level, both fugitive and venting emissions.

This study highlights the estimation of emission level, both fugitive and venting, of an existing gas transmission pipeline from Point A to Point B in West Java (Indonesia). Fugitive emissions are defined as unintentional leaks from any activities of energy production and distribution such as leaks from pipe connection, valves, fittings, and compressors. While venting emissions are typically a deliberate action associated with plant activities, or are produced when emergency situations require or produce a rapid reduction in process pressures. Sources of vented emissions include venting from glycol dehydrator vents, pneumatic devices, an planned or non-routine maintenance venting or blowdown [1].

A methane emissions study of this gas pipeline was done previously by calculating fugitive emissions based on Tier 1 and Tier 2 of Interstate Natural Gas Association of America (INGAA) due to the limitation of data resources [7]. As the development of the previous study, the emission level in this study is estimated using emission factors from Interstate Natural Gas Association of America (INGAA) and Intergovernmental Panel on Climate Change (IPCC). Furthermore, emission level is also simulated using emission factors for Russian gas transmission pipeline system [6]. Flow rate variation is simulated as well in order to find correlation between the flow rate and emission level. Gas flow rate is varied according to actual condition of gas flow on site and initial design of gas flow.

2. Data and calculation
This study assessed the system of gas pipeline transmission from A to B as illustrated by Figure 1 with detail information on Table 1. In this study, the emission level is estimated by multiplying emission factors to activities data. The result of calculation is total emission consists of fugitive and venting emissions both for operation and design flowrate condition.

There are 3 tiers in estimating the emission of gas pipeline system by referring to INGAA guidelines. While emission level calculation based on IPCC guidelines is performed only for Tier 1 which is inline with National GHG Inventory Guidelines of Indonesia [8]. In this study, emission factors for Tier 1 IPCC are choosed for developing countries with economies in transition. Basically, IPCC has 3 levels of emission assessment, from Tier 1 to Tier 3. However, Tier 2 and Tier 3 approaches can be implemented in a country that has detailed production statistics and infrastructure data, based on a compilation of oil and gas companies reports, which then can be developed to calculate the national emission factor [9].

There are 2 types of Russian gas pipeline emission factors used in this study i.e emission factors assessed from five Russian gas compressor stations and from extrapolation for Russian long distance gas transmission pipeline. The result of both fugitive and venting emission is converted from CH4 to CO2 equivalent by multiplying CH4 emission to 21.

3. Result and discussion
3.1. Emission level estimation as INGAA methodology
Generally, fugitive emissions are the biggest methane emission source account for transmission sector [1]. This phenomenon is also found in the calculation result of this study. As presented by table
2, total emissions significantly come from fugitive emissions. From calculation results of Tier 2 and Tier 3, ratio of fugitive emissions to total emissions are 62% and 59% respectively to total emission of gas pipeline with operation flow rate condition. The similar trend is also found when calculating the emission level with design flow rate condition, 54% and 57% respectively for Tier 2 and Tier 3. For Tier 1, fugitive emission contributes 67% to total emissions for both conditions of gas flow rate.

Fugitive emissions show higher value than venting emissions because of the higher emission factors. Fugitive emissions highly tend to occur because these emissions are difficult to be detected. Different from fugitive emissions, venting emissions have lower risk to occur as these emissions are emitted from emergency situation or over pressure condition in process which could be anticipated with several planned preventive actions.

Tier 1 approach only needs length of pipe as activity data without considering other process parameters. The result of Tier 1 estimation is used as basic or initial estimation and could be used as reference and recommendation for environmental assessment in order to obtain government permission.

Figure 1. Scheme of gas transmission pipeline system from A to B in West Java.

Table 1. Activities data of gas transmission pipeline system from A to B in West Java.

| Activity                                      | Value                  |
|-----------------------------------------------|------------------------|
| Pipe length                                   | 218 km                 |
| Pipe material                                 | Protected Steel        |
| Pipe branch                                   | 18                     |
| Number of gas compression station             | 3                      |
| Number of gas compression station shop        | 3                      |
| Number of metering and regulator station (MRS)| 1                      |
| Actual gas throughput                         | 196,161,95 MMSCFY      |
| Design gas throughput                         | 551,150 MMSCFY         |
| Type of MRS                                   | Transmission Interconnected |
| Type of compressor                            | Centrifugal            |
| Number of gas-operated pneumatics actuators   | 426                    |
| Number of continuous bleed pneumatics         | 399                    |
| Number of turbine valve operator              | 25                     |
| Number of pneumatic valve operator            | 2                      |
| Number of isolation valve operator            | 10                     |
| Number of MRS isolation valve                 | 1                      |
| Number of gas compression control loop        | 3                      |
| Number of MRS control                         | 1                      |

For Tier 2, the calculation needs more data activity than Tier 1. Thus, the estimation result is expected to be more accurate. To perform Tier 2 estimation for fugitive emissions, several activity data are needed such as pipe length, the number of gas compressor station, as well as the number of metering and regulator station. Different activity data are used in order to calculate venting emission level. These emissions are estimated by venting emissions from glycol dehydrator which are
calculated from annual gas flow rate or throughput and by venting emissions from pneumatic controller.

For Tier 3, the set of data activity is almost similar to Tier 2. However, Tier 3 is more detail as it includes the material of pipe and type of compressor for fugitive emissions. Moreover, Tier 3 also puts activity data of pipeline length, number of compressor station, and number of metering and regulator station both for fugitive and venting emissions estimation. For venting emissions, the type of pneumatic controller and actuator is considered as well as emissions from pneumatic driven isolation valves and control loops. In addition, pipe material is also considered in estimating emission level as it affects the pipe corrosion rate. Higher corrosion rate means higher risk of cracked pipe which gives possibility of natural gas to be emitted to atmosphere. Plastic is considered as a very good material for pipe and presented with lowest emission factor than cast iron, protected steel, and unprotected steel [1,3]. However, this material is not common for gas transmission pipeline due to its material properties [1].

### Table 2: Estimation results of emission level of point A to B gas pipeline as INGAA Guidelines.

| Tier | Fugitive Emission (Tonnes CO₂ equivalent/year) | Venting Emission (Tonnes CO₂ equivalent/year) | Total Emission (Tonnes CO₂ equivalent/year) |
|------|-----------------------------------------------|-----------------------------------------------|--------------------------------------------|
|      | Actual gas flow rate | Design gas flow rate | Actual gas flow rate | Design gas flow rate | Actual gas flow rate | Design gas flow rate |
| Tier 1 | 6,371.10 | 6,371.10 | 3,162.46 | 3,162.46 | 9,533.56 | 9,533.56 |
| Tier 2 | 36,131.43 | 36,131.43 | 21,863.18 | 30,184.07 | 57,994.61 | 66,315.50 |
| Tier 3 | 84,869.24 | 84,869.24 | 56,715.86 | 65,036.74 | 141,585.10 | 149,905.98 |

The gas flow rate has effect on the venting emission both for Tier 2 and Tier 3 as these Tiers consider the vented emission from glycol dehydrator unit and quantified by the flowrate of gas processed in glycol dehydrator unit. Basically, there is no glycol dehydrator from Point A to Point B. However, before entering the transmission line, the natural gas is passed to glycol dehydrator in processing unit and this process is considered in Tier 2 and Tier 3. Glycol dehydrator is a unit to eliminate water content in natural gas with glycol as absorbent. In the gas dehydration process, glycol will absorb not only water but also green house gas such as CH₄ and CO₂ which will be released to atmosphere at the end of dehydration cycle process.

The factor of compression has significance contribution to the emission level according to Tier 2 and Tier 3 approaches in this study. The emission generated from compression station is more than 60% of total emission for Tier 2. While, the emission quantified by number of centrifugal compression contributes to more than 50% of total emission for Tier 3. Compressor is used to provide adequate pressure of the gas which is flowing in the pipeline to reach end users. Compressor is worked as the result of the driver, typically a gas or diesel engine or gas turbine. The driver of compressor is a potential leak source that emit GHG emissions, particularly CH₄ and CO₂.

Particularly in Tier 3, type of compressor is considered in estimating the emission level. There are 2 types of compressor in this methodology, reciprocating and centrifugal compressors with different emission factors. To reduce compressed natural gas being emitted to atmosphere, reciprocating type has flexible rings at the piston as a seal while centrifugal compressor has design with wet seal or dry seal. However, the design of wet seal centrifugal compressor leads more emission vented to atmosphere than dry seal centrifugal compressor and reciprocating compressor. Due to this reason, emission factors of centrifugal compressor are higher than reciprocating type.

The use of dry seal compressor actually has been applied by several oil and gas companies due to as it is more environmentally friendly but also more cost saving. Uptigrove et al. reported that dry seal compressor is more economic than wet seal type with $85,293 saving per year [10].
3.2. Emission level estimation as IPCC methodology
IPCC only provides emission factors for Tier 1 approach. Emission factors for Tier 2 and Tier 3 approaches are not available in IPCC guidelines because of the difference in technology, standard, and regulation in many countries. In this study, due to lack of resources to determine national specific emission factors and additional data needed for Tier 2 and Tier 3 approaches, thus only Tier 1 is applied in estimating the emission level. Tier 1 IPCC only considers the flow rate parameter to be multiplied to given emission factors. With the same object of pipeline, total emission for actual and design flow rate conditions are 15.035 and 42.243 tonnes CO$_2$ equivalent/year respectively. Both of these flow rate conditions contribute 79% of fugitive emissions to total emissions level.

When referring to Russian gas pipeline system, the highest emission factors come from compressor activities for both approaches [6]. In this estimation, the emission level is not affected by flow rate variation. Detail calculation results are presented on Table 3.

4. Review of different estimation results
Fundamentally, most of methodologies discussed above concern on almost similar activity data for emission factors such as properties of pipe, valve systems, gas compressor station, and component of gas compressor station. However, the use of different methodologies gives different results of emission level as presented on Table 3.

Table 3. Estimation results of emission level of point A to B gas pipeline with different methodologies

| Guidelines              | Approaches | Total GHG Emissions (Actual gas flow rate) [Tonnes CO$_2$ equivalent/year] | Total GHG Emissions (Design gas flow rate) [Tonnes CO$_2$ equivalent/year] |
|-------------------------|------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| INGAA                   | Tier 1     | 9,533.56                                                                      | 9,533.56                                                                  |
|                         | Tier 2     | 57,994.61                                                                     | 66,315.50                                                                 |
|                         | Tier 3     | 141,585.09                                                                    | 149,905.98                                                                |
| IPCC                    | Tier 1     | 15,035.01                                                                     | 42,243.40                                                                 |
| Russian Pipeline System | Assessment of 5 gas compressor stations | 488,627.80                                                                  | 488,627.80                                                                 |
|                         | Extrapolation for Russian long distance pipeline system | 3,044,255.19                                                           | 3,044,255.19                                                              |

Total emissions based on extrapolation for Russian long distance pipeline system gives highest result than other methods. This extrapolation basically is developed from direct assessment activities to collect the data. However, the geographic condition, infrastructure, technology, and equipment as objects of assessment are completely different from condition of gas transmission pipeline in this study. For example, the compressor power of Russian pipeline system is varied from 6 to 25 MW, while the compressor power in the pipeline system of this study is 2 to 3 MW.

Similar condition is found in INGAA guidelines as well. Although INGAA has become guidelines for many gas transportation companies in many countries but emission factors and activity data in the guideline were developed from direct sampling of gas transmission pipeline system located mostly in North America. The technology and operation condition are not exactly similar as pipeline system in Indonesia.

For IPCC guidelines, emission factors for Tier 1 are developed by considering geographic, economic, and technology conditions of group of countries. Thus, activity data and emission factors in IPCC are different for developed and developing countries. However, it needs to use higher level of “Tier” in order to get more accurate estimation. In IPCC guidelines, emission factors for Tier 2 and
Tier 3 are not provided due to the fact these data reflect actual condition of every country thus cannot be generalized.

5. Conclusion and recommendation
Some agencies provide guidelines to estimate the emission level of natural gas pipeline system with different emission factors and activity data. As the result, the emission estimation has various levels when using various guidelines and needs to be validated. For this validation purpose, the best method is direct sampling to the object. However, as it takes more time and cost, a rough estimation for validation purpose could be initiated by exploring supporting data related to gas losses in the gas flow system during the process of transportation. These losses are then considered as methane which is emitted to atmosphere.

In estimating emission level, there are some methodologies with different reliability level. Direct measurement is still the most accurate method but it has limitation as it needs more time, resources, and safety considerations. Practically, the use of existing emission factors is easier to be applied when related data and resources are not available. On the other hand, default emission factors mostly are not reliable because it generalizes conditions of assessed objects which are quite different from operation scenarios as the basis of developed emission factors. Thus, it is recommended that Indonesia has national database of emission factors based on source testing to accommodate actual object conditions. However, once these national emission factors have been established, continuous evaluation will be needed to keep the reliability of these emission factors particularly when conditions change on site.

6. References
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