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Utilizing Methane Fugitive Emission Data from Core Drilling Analysis for ESG Improvement Innitiatives at PT Borneo Indobara

Mohamad Soleh Joko Santoso[1], Yudo Anggoro[2]
Institut Teknologi Bandung, Indonesia[12]
Emails: mohamad_santoso@sbm-itb.ac.id[1]; yudo.anggoro@sbm-itb.ac.id[2]

ABSTRACT:
Fugitive methane emission from open-pit coal mining operations is one of the significant contributors to greenhouse gas (GHG) emissions in the Scope 1 category. In Indonesia, the calculation method still widely used is Tier 1 from the IPCC 2006 guidelines, which is based on global default emission factors and does not account for local site-specific geological conditions such as overburden thickness and actual gas-in-place content. This study aims to apply the implementation of Tier 3 from the IPCC method, based on direct methane gas measurement, to produce more accurate and applicable estimates of methane fugitive emission. The study was conducted at PT Borneo Indobara (BIB) by taking coal samples through exploration drilling and methane gas desorption analysis using international standards such as GPA 2261 and ASTM D1946. The results showed that the average actual methane content of 0.40 m^3/ton was much lower than the Tier 1 default of 2 m^3/ton, indicating the potential for reducing CO_2e emissions by changing the baseline calculation from Tier 1 IPCC to Tier 3 IPCC. This suggests a potential reduction in CO_2e emission baseline estimates of up to 80%, which could translate into substantial carbon tax savings. The implementation of Tier 3 contributes to increased accuracy in GHG reporting, compliance with ESG standards, and fairer, data-based carbon tax calculations. This study recommends the use of Tier 3 as a transparent, scientific, and replicable approach in other coal mines in Indonesia to support national decarbonization policies and strengthen the credibility of domestic carbon markets.
Keywords: Tier 3, IPCC, fugitive methane, coal, GHG emissions, PT BIB, ESG Policy, carbon tax.

INTRODUCTION

Tanah Bumbu Regency is one of the strategic areas in South Kalimantan Province with significant coal mining activity, which has drawn attention due to its environmental impact. (GEMS) located in South Borneo, has been operational since 2005, initially producing 168 thousand tons/year and gradually increasing production to 1 million tons/year in 2007. Between 2008 and 2010, production ranged between 1.1 to 1.3 million tons/year, and total coal production reached approximately 13 million tons by 2011 (Santoso et al., 2014). The feasibility study was revised to target 36 million tons per year by 2017, and currently, PT BIB operates at 46.8 million tons/year, with plans to reach 54 million tons/year (Wahyudi et al., 2018). Coal mining activities, from overburden management to barging processes, contribute to greenhouse gas emissions and environmental degradation (Li et al., 2019; Sharma & Kumar, 2020). Recent studies have highlighted the importance of adopting sustainable mining practices and emission control technologies to mitigate environmental impacts (Zhou et al., 2021; Putra et al., 2022; Sun et al., 2023; Hartono & Susanto, 2022).

One of the most significant environmental issues that are associated with coal mining is the coal methane fugitive emission (Kholod et al., 2020; Wang et al., 2019). In coal mining operation especially open pit mine, methane is naturally trapped inside coal seams and surrounding strata and it is released during mining activities. These unintended releases of methane into the atmosphere classified as fugitive emission. The 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories define emission from coal mining as follow: "Methane is the major greenhouse gas emitted from coal mining and handling. The emission occurs during the mining and post-mining process and are referred to as 'fugitive emission' because they are not collected and combusted" (IPCC, 2006, Vol.2, Ch. 4, p.4.3). Based on the referenced Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines for National Greenhouse Gas Inventories (Volume 2, Chapter 4), several countries such as the United States, Australia, China, and India have developed advanced methane emission estimation approaches used on IPCC. The IPCC is a scientific group established by the United Nations (UN) to assess all the science related to climate change. These approaches rely on region-specific emission factors and direct field measurements such as desorption tests and pre-drainage gas capture, allowing for more accurate and representative emission inventories tailored to local geological conditions as shown in Table 1.

Table 1. Coal Mine Emission Factor Around the World (IPCC, 2006)

Country	Coal Basin / Region	Coal Rank / Type	Calorific Value (GAR, kcal/kg)	Average CH4 Emission Factor (m^3 CH_4/tonne coal)	Source / Reference
USA	Appalachian Basin	Bituminous	6,000–6,700	10,0	IPCC 2006 Vol.2 Ch.4 Annex 2A.1
Australia	Bowen Basin	Bituminous/Sub-bituminous	5,800–6,400	8,5	IPCC 2006 Vol.2 Ch.4 Annex 2A.1
China	Shanxi Province	Bituminous	5,500–6,000	6,5	IPCC 2006 Vol.2 Ch.4 Annex 2A.1
India	Gondwana Basin	Bituminous/Sub-bituminous	4,800–5,500	2,5	IPCC 2006 Vol.2 Ch.4 Annex 2A.1
Indonesia	Asam-Asam Basin	Sub-bituminous	4,200–4,800	X	No Reference

The application of Tier 1, Tier 2, and Tier 3 methodologies from the IPCC (Intergovernmental Panel on Climate Change) in the mining industry is important to assess greenhouse gas (GHG) emissions produced. The three-tier approach offers a different framework for calculating emissions based on the detail and complexity of the available data.

The Tier 1 method is the simplest method that uses default emission factors set by the IPCC. This approach is usually used when local specific data is not available, because using global estimates can risk producing high uncertainty (Pinem et al., 2020). Research shows that the use of

Tier 1 emission factors can lead to higher estimates compared to field measurements in the oil and gas sector, where Tier 1 estimates for CH_4 and CO_2 can be up to 51 times higher than measured (Pinem et al., 2020). In the mining context, the use of Tier 1 can provides a rough picture of emissions, but more accurate data is often needed. Detail Tier 1 can be seen on Table 2 below.

Table 1. Methane Fugitive Emission Factor at Tier 1 Table (IPCC, 2006)

Emission Factor	Surface mining	Post mining	Remarks
Low CH4 emission factor	0,3 m3/ton	0,0 m3/ton	Average OB depths < 25 m
Average CH4 emission factor	1,2 m3/ton	0,1 m3/ton	25 m < average OB depth < 50 m
High CH4 emission factor	2,0 m3/ton	0,2 m3/ton	Average OB depths > 50 m

Source: IPCC, 2006 (edited)

Moving on to Tier 2, this approach is expected to reduce uncertainty by relying on country-owned or sector-specific data to increase the accuracy of estimates. Tier 2 methods use more specific parameters and are often based on local or national data, and as found in various studies, they provide more detailed results, although they still depend on the quality of the available data (Appuhamy et al., 2016; Benaouda et al., 2019). For example, the application of the Tier 2 method in calculating emissions from enteric fermentation in cattle showed that revisions to the parameters used can produce more accurate emission estimates compared to Tier 1 (Kouazounde et al., 2015; Jo et al., 2016). However, there are still challenges in terms of the availability and reliability of the required data.

Tier 3 is the most complex approach among the three methods. It involves the use of specially engineered models to calculate emissions based on various parameters and conditions specific to a particular location or system (Karimi-Zindashty et al., 2011). This method is able to capture variability in the processes that produce GHG emissions and provide more accurate estimates compared to other tiers, especially in the context of mining which often involves complex and dynamic processes (Flynn et al., 2005). Tier 3 requires greater investment in data collection and model development but has the potential to provide very useful information for decision making and mitigation policies (Graham et al., 2022). The Tier 3 approach, as outlined in the 2006 IPCC Guidelines for National Gas Inventories, represents the most advanced and specific method to estimate fugitive methane emission factors. Tier 3 involves direct, mine-level measurements that provide a much more accurate representation of actual emissions.

According to IPCC (2006, Vol.2, Chapter 4), the Tier 3 methodology is based on "*direct measurement from ventilation air or degasification system or from coal samples (e.g., canister desorption).*"— IPCC 2006, Vol. 2, Ch. 4. In 2025 Indonesia still need to be developing Tier 2 IPCC basis. Based on Third Biennial Update Report Under the United Nations Framework

Convention on Climate Change by Indonesian government in 2021, The default emission factor of 0.3 m^3 CH_4 per ton of coal assigned to all surface coal mines in Indonesia.

If methane emission applied by depth reference more than 50 m overburden thickness, it will probably make overestimated calculation for methane fugitive emission. In fact, many coal mines in East Kalimantan and South Kalimfantan have overburden depths start between 30 and 60 meters even more, such as the Kaltim Prima Coal mine at East Kalimantan and also at PT BIB in South Kalimantan, which ranges between 50 to 130 meters depth for current year (2025) mining operation.

The use of Tier 3 helps to ensure conformity with sustainable disclosure standards like the Global Reporting Initiative (GRI 305), which mandates that firms disclose the techniques and assumptions that are utilized in the process of computing greenhouse gas emissions. Direct measurement techniques are the best practice for reporting Scope 1 methane emissions in high-emission industries such as coal mining. These approaches meet important GRI principles such as accuracy, completeness, and transparency. The Tier 3 approach offers a method for evaluating emissions that is supported by an extensive body of scientific evidence. This method is particularly ideal for mines that have a deeper overburden, a deeper gas concentration, or strategic ESG disclosure requirements. Transitioning to Tier 3 can significantly enhance the reliability and environmental accountability of emission inventories for Indonesian operations such as PT BIB, where the overburden depth frequently exceeds 50 meters and where the methane concentration is likely to be overestimated under Tier 1. Tier 3 adoption also requires significant investment in measurement technologies and dedicated manpower who certified in ASTM and GPA testing which is not available on PT BIB coal mine site. It is necessary to identify the root of the problem using the right method to answer why data for Tier 3 at PT BIB is not available yet.

METHOD

The accomplishment of the methane emission identification requires a baseline calculation. As a result of the existence of a few references, it is necessary to carry out the process of developing CH_4 emission data from coal based on Tier 1 and Tier 3. The methodologies used for emissions detection and quantification, and the importance of incorporating such data into sustainability reporting and corporate decision-making. GRI 305-7 requires companies to report other air emissions, including CH_4 (methane), in tons per year. How to measure and calculate methane in coal mining according to GRI 305-7 below.

Fugitive Emission Estimation

Using an estimation method based on emission factors from the IPCC Tier 1. Guidelines for National Greenhouse Gas Inventories with basic formula below.

TIER 1: GLOBAL AVERAGE METHOD – SURFACE MINES

Methane emissions = CH_4 Emission Factor • Surface Coal Production • Conversion Factor

Where units are:

Methane Emissions (Gg year^{-1})
CH_4 Emission Factor (m^3 ton^{-1})
Surface Coal Production (ton year^{-1})
Emissions Factor:
Low CH_4 Emission Factor = 0.3 m^3 ton^{-1}
Average CH_4 Emission Factor = 1.2 m^3 ton^{-1}
High CH_4 Emission Factor = 2.0 m^3 ton^{-1}
Conversion Factor:

This is the density of CH_4 and converts volume of CH_4 to mass of CH_4. The density is taken at 20˚C and 1 atmosphere pressure and has a value of 0.67 ● 10^{-6} Gg m^{-3}. For the Tier 1 IPCC approach, it is good practice to use the low end of the specific emission range for those mines with average overburden depths of less than 25 meters and the high end for overburden depths over 50 meters. In this research, fugitive methane emissions will be calculated using tier 1 of global average emission compared with Tier 2 and Tier 3 method using direct measurement methane fugitive emission data by desorption method. During that time, Tier 3 not ready due to some reason. The reason identified with root cause analysis.

Root Cause Analysis

The identification about why there is no coal methane fugitive emission identification before could be seen on the fishbone diagram (Ishikawa) in Figure 4. In this research, fishbone diagram is used to identify the root cause of the absence of methane fugitive emission measurement at PT BIB coal mining operations. Several factors are holding back progress in methane emission measurement. One of the biggest challenges is the lack of trained personnel, no one has been specifically assigned or equipped with the skills to plan, gather, or analyze methane gas data. On top of that, there are no clear procedures in place. Without a Standard Operating Procedure (SOP) or Job Safety Analysis (JSA), methane data collection hasn't become part of the company's regular workflow.

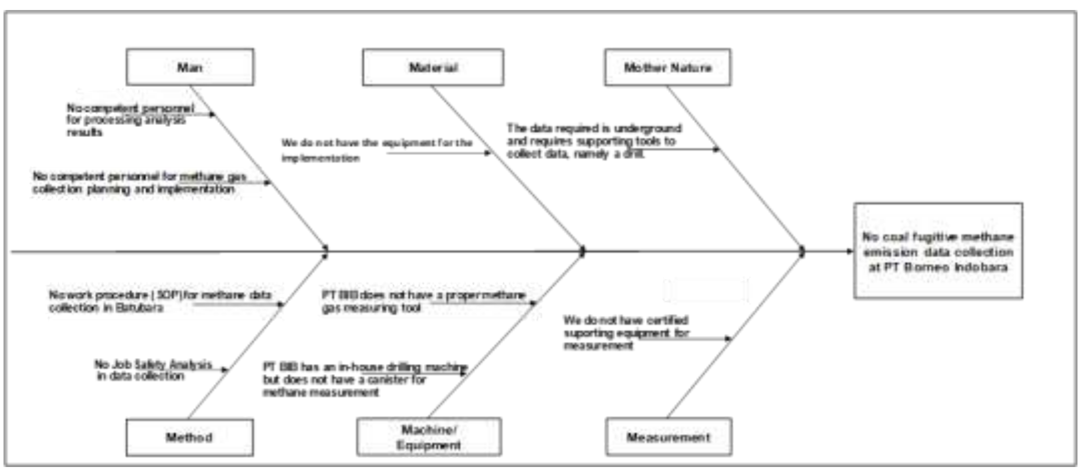

Figure 1. Root Cause Analysis

Another major issue is equipment. The needed tools such as gas canisters and proper analyzers simply aren't available, making it impossible to carry out accurate measurements. Even if there were tools, there's no system to calibrate or validate the data, which means results could be unreliable.

There is also a deeper challenge, methane in this context lies within subsurface geological formations. Accessing it would require initial drilling, which has not been prioritized. These issues from gaps in manpower and procedures to missing equipment and geological hurdles paint a clear picture. If PT BIB wants to move toward Tier 3 IPCC standards and meet future ESG expectations, these obstacles must be addressed and solved. To solve this obstacle, Focus Group Discussion is needed with some experts on this field due to PT BIB still has no competent persons yet in the methane fugitive emission capture, processing & reporting.

Focus Group Discussion

To strengthen the quantitative analysis and contextual understanding of methane emission estimation challenges in Indonesia, Focus Group Discussions (FGD) were conducted with key stakeholders in the coal mining sector especially by gas and ESG experts. The FGD aimed to gather insights on the current practices, obstacles, and opportunities related to the measurement and reporting of fugitive methane emissions. Focus group discussion was held using Zoom online meeting due to the participants are in different areas and attended by key person experts in ESG especially in methane fugitive emission. Participants in the FGD included representatives from RPM Global Australia, Geogas Indonesia, BIB, and Geoservices Indonesia. The discussion covered topics such as the feasibility of applying IPCC Tier 2 and Tier 3 methodologies, the availability of emission monitoring infrastructure, data transparency issues, and company readiness and risk to implement each Tier.

The following table summarizes the key differences among the three IPCC tiers from FGD.

Table 3. Comparative Analysis of Tier Methodologies

Aspect	Tier 1	Tier 2	Tier 3
Data	Global default factors	Country/basin-specific data	Direct measurement (mine-specific)
Accuracy	Low (high uncertainty)	Moderate	High (low uncertainty)
Cost	Low	Medium	High
Best suited for	Countries with limited data	Countries with regional capacity	Countries with advanced capacity
Key category?	Not recommended	Suitable	Recommended
Availability Data	Available globally	Often unavailable	Can be obtained with investment

Source: Primary data, 2025 (edited)

Direct Measurement Method

The measurement of methane emissions in coal mining should be based on direct monitoring named Tier 3 IPCC method to guarantee accuracy and comply to international standards. This Tier 3 methods including canister desorption, borehole gas sampling, and ventilation air monitoring, based to technical standards such as ASTM D1946, and GPA 2261 from the Gas Processors Association. The standards delineate procedures for analyzing gas composition through gas chromatography and additional methodologies. Utilizing these standardized methods complies with GRI 305-7 disclosure requirements and IPCC 2006 Guidelines, specifically Tier 3 methodologies, which prioritize site specific and direct measurement rather than default factors.

Furthermore, the emission factors adopted in the IPCC 2006 Guidelines were developed based on coalfields located in the countries such as Australia, China, India and Canada region which possess higher calorific value coal compared to PT BIB's coal and also different characteristic geological basin. Given these contextual differences, this research seeks to test hypothesis for Tier 1 and also possibility transition to use Tier 3. Improving the accuracy of fugitive methane reporting would not only strengthen the company's GHG inventory but also enhance transparency in alignment with GRI 305-7 and contribute to improved ESG ratings and climate resilience planning. PT BIB is fully aware of the high level of Mining Safety risk and the environmental impact of coal mining activities carried out by the company.

This research focusing in one of initiatives such as decarbonization. Focussing on decarbonization from coal methane fugitive emission. For the decarbonization we should identify the source of emission or base line of emission before do some improvement initiatives. The identifying source especially emission-based lines could help us to do the proper and measurable decarbonization. The coal production plan will be used as multiplier factor in fugitive methane emission.

RESULTS AND DISCUSSION

For Tier 3 IPCC Method data capturing, gas volume measurement has been carried out for 6 drillholes at two different pit locations, i.e Drillhole FGT_01, FGT_02 & FGT_03 in Pit Girimulya and Drillhole FGT_04, FGT_05 & FGT_06 in Pit Kusan with a total of 80 samples represent all stratigraphy on the mining pits where have the majority reserves number.

Gas Content Result from Desorption Method

From the results of gas measurements in the field after calculations have been made, values for lost gas (Q1), measurable gas (Q2), residual gas (Q3), and total gas content (Qm) are obtained which are summarized of the corrected gas volumes that consist of the value of Q1, Q2, and Q3 as presented in gas content RAW and gas content DAF. Overall, from 6 drillholes was carried out gas testing measurements at PT BIB, at the Pit Girimulya and Pit Kusan with an average gas content value of 0.34 m^3/t, the smallest value of 0.08 m^3/ton and the largest value of 1.29 m^3/t can be classified as a small gas classification (less than 1.5 m3/t). Increased gas was only found in several drillholes at certain depths in Pit Girimulya and Pit Kusan, especially in deep coal seam (coal seam E & coal seam D). In the Pit Girimulya, the gas content value becomes smaller towards the south, as do the conditions in the Pit Kusan.

Gas Composition Result from Desorption Method

After gas content was identified, we go to next stage to identify gas composition. In this stage we can get the quantity figure for Methane Volume. Eighty gas samples selected from each canister sample were analyzed for gas composition using a gas chromatograph. The results of the analysis are presented in Table 4.

For example, from After Corrected to Air Free (%) column or the content of the elements after correction for air or the main components of air (oxygen and nitrogen) are removed from the gas sample, show the average analysis results on FGT_01 are hydrocarbons (CH4+) 86,13%, nitrogen 6,50%, carbon dioxide 7,23% and carbon monoxide 0,14%. The gas compositions of all boreholes are relatively consistent and none of the samples is considered anomalous.

Table 4 The Summary Result of Gas Composition Analysis

Gas Sample	As Analyzed (%)						After Corrected to Air Free (%)				
	CH_4+	O_2	N_2	CO_2	CO	GCV	CH_4+	N_2	CO_2	CO	GCV
FGT_01	5,84	19,72	73,90	0,53	0,01	2,21	86,13	6,50	7,23	0,14	32,72
FGT_02	2,27	20,56	76,92	0,24	0,00	0,86	81,79	10,53	7,49	0,19	31,19
FGT_03	5,97	19,60	73,64	0,79	0,01	2,25	79,30	8,44	12,02	0,24	30,04
FGT_04	12,21	18,27	68,60	0,92	0,01	4,61	81,80	5,27	12,75	0,19	30,85
FGT_05	9,27	18,78	70,57	1,36	0,02	3,49	80,06	5,67	14,04	0,23	30,16
FGT_06	7,95	19,24	72,29	0,50	0,01	3,00	87,68	6,81	5,36	0,16	33,14

Source: Primary data, 2024 (edited)

Gas Summary Result for Tier 3 Method

For calculating fugitive emissions in accordance with the IPCC Tier 3 methodology, the gathering and statistical analysis of data correlation to methane gas (CH3) from coal seams is an essential component. In this part, the findings from a dataset consisting of eighty gas samples are summarized. More specifically, the parameter "Vol CH4 +" (methane volume in cubic meters per ton of coal) is evaluated to determine whether or not the data set is statistically sufficient to support a Tier 3 estimating approach. For Tier 3 calculation using formula below applied on example calculation in FGT 01 (Drillhole Fugitive 01).

$$\textit{Methane Volume } (m^3/ton) = \textit{Total Gas Volume } (m^3/ton) \times (100\%\textit{Methane})$$

Example:

Methane Volume (m^3/ton) =Total Gas Volume (m^3/ton) × (100%Methane)

Example:

Total Gas Content = 0.21 m^3/ton

% Methane (CH_4) = 82.74%

Volume CH_4 (m^3/ton) = 0.21×82.74/100 = **0.17 m^3/ton**

Table 5. The Summary Result of CH4 Sample Calculation on FGT 1

Drill Hole	Canister No	Gas Content Result				Gas Composition Result					Vol CH_4+
		Gas Content (m^3/t) DAF				After Corrected to Air Free (%)					
		(Q1)	(Q2)	(Q3)	(Qm)	CH_4+	N_2	CO_2	CO	GCV	
FGT_01	FGT_01_01D	0,00	0,16	0,04	0,21	82,74	6,78	10,40	0,08	31,95	0,17
	FGT_01_02D	0,01	0,10	0,05	0,17	82,64	11,51	5,43	0,42	31,32	0,14
	FGT_01_03D	0,00	0,09	0,04	0,14	86,65	3,11	10,16	0,07	32,72	0,12
	FGT_01_04D	0,01	0,12	0,04	0,17	79,45	10,69	9,78	0,08	30,48	0,14
	FGT_01_06D	0,02	0,24	0,11	0,38	87,47	5,70	6,64	0,19	33,01	0,33
	FGT_01_07D	0,06	0,30	0,11	0,47	82,06	9,58	8,19	0,18	31,44	0,39
	FGT_01_08D	0,02	0,28	0,11	0,41	90,72	5,49	3,66	0,13	35,75	0,37
	FGT_01_09D	0,02	0,31	0,10	0,43	87,42	7,19	5,32	0,07	32,94	0,38
	FGT_01_10D	0,06	0,47	0,11	0,64	88,88	2,53	8,53	0,06	33,49	0,57
	FGT_01_11D	0,04	0,45	0,11	0,59	85,27	5,02	9,56	0,15	32,12	0,51
	FGT_01_12D	0,04	0,50	0,12	0,66	87,62	6,19	6,09	0,10	33,00	0,58
	FGT_01_13D	0,10	0,65	0,13	0,89	85,14	6,61	8,12	0,13	32,08	0,76
	FGT_01_14D	0,07	0,70	0,12	0,89	88,19	4,40	7,30	0,10	33,25	0,78
	FGT_01_15D	0,09	0,74	0,12	0,95	91,54	6,19	2,03	0,25	34,49	0,87

Source: Primary data, 2024 (edited)

Statistical analysis was conducted on a dataset containing 80 methane gas measurements (expressed in cubic meters per ton of coal) to evaluate the distribution and variability of gas content in coal seams as seen on Table 6. The primary objective was to determine whether the data could support the development of reliable emission factors, particularly for application in Tier 3 greenhouse gas inventories.

Table 6. Statistics for Gas CH4 Volume for Tier 3 at PT BIB

Statistic	Value
Mean	0,40 (m3/ton)
Median	0,32 (m3/ton)
Standard Deviation	0,31 (m3/ton)
Kurtosis	1,61
Skewness	1,39
Range	1,43
Minimum	0,06 (m3/ton)
Maximum	1,50 (m3/ton)
Count	80

Source: Primary data, 2024 (edited)

The average gas content recorded across all samples was 0.40 m³/ton, indicating a moderate level of methane typically present in the analyzed coal. However, the presence of a median value of 0.32 m³/ton, which is lower than the mean, points to a distribution skewed towards higher values. This suggests that while most samples exhibit relatively low methane content, a subset of data contains significantly higher concentrations, pulling the average upwards. This initial Tier 3 analysis at PT BIB show that none of samples have gas content volume more than 2 m³/ton as stated in IPCC 2006 while all off-overburden depth more than 50 m thick. After we get Tier 3 methane emission fugitive volume, we can make comparation between some calculations using IPCC method.

Calculation CO_2 Emission Using Tier 1 Method

The Tier 1 method, as defined by the IPCC, uses default emission factors and generalized activity data to estimate CO_2 emissions. This approach is designed for simplicity and for countries or entities lacking specific field data.

Emissions CO_2e (kg) = Production (ton) × Emission Factor (m³ CH_4/ton) × CH_4 Density (kg/m³) × GWP_CH_4

Emissions CO_2e (ton) = Emissions_CO_2e (kg) / 1,000

Where:

- Emission Factor (Tier 1) = 2.0 m³ CH_4/ton
- CH_4 Density = 0,67 x 10-6 Gg/m^3
- GWP(CH_4) = 28

Example Calculation:

If year 2025 coal production is 51,200,000 tones:

Emissions CO_2e = 51,200,000 × 2.0 × 0,67 x 10^{-6} × 28 = 1.921.024 ton CO_2e

Example calculation using 2025 production plan to provides an estimate of the amount of methane emissions that are comparable to carbon dioxide (CO2e) from coal production process. Production plan in 2025 is 51.2 million tons of coal, the formula considers an emission factor of 2.0 m^3 CH_4 per ton, a methane density conversion of 0.67 kg/m^3, and a global warming potential (GWP) of 28 for methane. Approximately 1,921,024 tons of carbon dioxide equivalent are the outcome in a year or 0,03752 ton CO_2e per ton coal.

Calculation CO_2 Emission Using Tier 3 Method

The Tier 3 methodology provides the most precise emission estimate among all tiers because it utilizes direct field data collected from PT BIB's mining site, passing the generalized assumptions used in both Tier 1 and Tier 2. This method ensures transparency and scientific accuracy by reflecting the actual gas content measured on site. Tier 3 data such as that from PT BIB can serve as a foundation for constructing more representative Tier 2 factors at the national level, especially if similar data sets are collected across Indonesia. The Tier 3 measurements at PT BIB can represent the geological conditions of the Asam-asam Basin and may be considered a valid reference for other coal operations within South Kalimantan that have similar basin structures and formations. Example Calculation:

Emissions CO_2e (kg) = Production (ton) × Emission Factor (m³ CH_4/ton) × CH_4 Density (kg/m³) × GWP_CH_4

Emissions CO_2e (ton) = Emissions_CO_2e (kg) / 1,000

Where:

- Emission Factor (Tier 2) = 0.40 m³ CH_4/ton
- CH_4 Density = 0,67 x 10-6 Gg/m³
- GWP(CH_4) = 28

Example Calculation if year 2025 coal production is 51,200,000 tons below.

Emissions CO_2e = 51,200,000 × 0.40 × 0,67 x 10-6 × 28 = 384,205 ton CO_2e

In year 2025 estimated coal production will be 51.2 million tons of coal and a Tier 3 emission factor of 0.40 m³ CH_4 per ton, CO2e methane emissions are anticipated at 384,205 tons CO2e. The calculation assumes a methane density of 0.67 kg/m³ and a GWP of 28. Tier 3 data can provide more precise emission values of mine specific CO2e resulting in an 80% drop from Tier 1 estimates of 1,921,024 tons CO_2e (using an emission factor of 2.0 m³ CH_4/ton). This may prevent overestimation in national inventories. Using Tier 3 method makes CO_2e emission reduction reach until 80% from Tier 1 method, the benefit cost ratio can be estimated. Especially in potentially saving of carbon tax. Which means we can reduce carbon tax if we use Tier 3 IPCC when carbon tax applied so we can anticipate the future cost. We can exclude Tier 2 method for calculation due to Tier 2 not match with current actual depth condition at PT BIB.

Benefit Cost Ratio from Tier 3 Application

The Tier 3 methodology provides the most precise emission estimate among all tiers because it utilizes direct field data collected from PT BIB's mining site, passing the generalized assumptions used in both Tier 1 and Tier 2. This method ensures transparency and scientific accuracy by reflecting the actual gas content measured on-site. The Tier 3 implementation benefit can be simulated by calculation below if carbon tax IDR 30,000 multiply with CO_2e both Tier 1 and Tier 3 Result then comparing with the monitoring cost as seen on Table 7.

Example Calculation (2025):

If tax avoided (compared to Tier 1) in 2025 is IDR 46,104,576,000 and the monitoring cost is IDR 2,517,720,000 benefit cost ratio in 2025 could be simulated below.

BC Ratio_2025 = 46,104,576,000 ÷ 2,517,720,000 ≈ 18.31

Table 7. Benefit Cost Ratio Simulation Using Tier 3

IPCC Tier	IDR		USD		Remarks
	2025	LOM FS 54	2025	LOM FS 54	
Tier 1	57.630.720.000	703.656.458.400	3.601.920	43.978.529	Not Suitable
Tier 2	8.644.608.000	105.548.468.760	540.288	6.596.779	Not Applicable
Tier 3	11.526.144.000	140.731.291.680	720.384	8.795.706	Applicable
Tier 1 - Tier 3	46.104.576.000	562.925.166.720	2.881.536	35.182.823	
BCR	18	224	18	224	

Source: Primary data, 2024 (edited)

Based on the analysis, Tier 1 looks overestimate methane emissions because it uses a fixed default factor (e.g., 2 m³ CH_4/ton of coal) without considering local geological conditions and local coal rank. On the other hand, Tier 2 significantly underestimates emissions at PT BIB, as shown in the data, and is not applicable in this case because the method assumes overburden thickness below 50 meters while PT BIB's overburden is more than 50 meters. Therefore, the most accurate and appropriate approach is Tier 3, which uses direct field measurements to get actual site conditions. Although Tier 3 requires investment, for example IDR 2,517,720,000 in Tier 3 cost Project, the potential benefits such as verified emission values, improved ESG credibility, and eligibility for carbon initiatives can reach IDR 46,104,576,000. This results in a Benefit Cost Ratio (BCR) of 18.

The accuracy of Tier 3 data supports precise emission baselining, helps prevent overpayment of carbon taxes, and strengthens ESG reporting. When comparing emission results with those from Tier 1, the difference in potential tax exposure is substantial.

CONCLUSION

The most accurate method to measure coal methane (CH4) content at PT Borneo Indobara (PT BIB) is the Tier 3 methodology from the IPCC 2006 Guidelines, which relies on direct measurements such as canister desorption from coal core samples, in situ gas testing, and gas content analysis. Unlike Tier 1 and Tier 2 methods that use global or national average emission factors, Tier 3 provides mine-specific emission factors reflecting actual gas content and local geological conditions. Field data showed PT BIB's average methane emission at 0.40 m³/ton, significantly lower than the Tier 1 default of 2.0 m³/ton, indicating that Tier 1 overestimates emissions by up to 80%. Applying Tier 3 results leads to more accurate greenhouse gas inventories, regulatory compliance, and large carbon tax cost savings—potentially more than IDR 46 billion annually against a reasonable project investment. For future research, it is suggested to expand Tier 3 measurements across diverse mining sites in Indonesia to validate its broader applicability and to assess long-term impacts on national carbon reporting, sustainability disclosures, and carbon market mechanisms.

REFERENCES

Appuhamy, J. A. D. R. N., Vyas, D., Moraes, L. E., & McGeough, E. J. (2016). Models for predicting enteric methane emissions from dairy cows in North America, Europe, and Australia and New Zealand. *Global Change Biology, 22*(9), 3039–3056. https://doi.org/10.1111/gcb.13339

ASTM D 1946-90. (1994). *Standard practice for analysis of reformed gas by gas chromatography.*

Benaouda, M., Arbre, M., & Martin, C. (2019). Evaluation of the performance of existing mathematical models predicting enteric methane emissions from ruminants: Animal categories and dietary mitigation strategies. *Animal Feed Science and Technology, 256,* 114207. https://doi.org/10.1016/j.anifeedsci.2019.114207

Bursa Efek Indonesia (IDX). (2023). *Public data on annual and sustainability report disclosures.*

Retrieved from the official IDX website.

Flynn, H. C., Smith, K. A., Smith, J. U., & Williams, J. R. (2005). Climate- and crop-responsive emission factors significantly alter estimates of current and future nitrous oxide emissions from fertilizer use. *Global Change Biology, 11*(10), 1522–1535. https://doi.org/10.1111/j.1365-2486.2005.00998.x

Graham, M. W., van Wijk, M. T., & Rufino, M. C. (2022). Research progress on greenhouse gas emissions from livestock in Sub-Saharan Africa falls short of national inventory ambitions. *Frontiers in Soil Science, 2,* 927452. https://doi.org/10.3389/fsoil.2022.927452

Hartono, A., & Susanto, B. (2022). Environmental impacts and mitigation strategies in coal mining operations in Indonesia. *Environmental Science and Pollution Research, 29*(15), 22245–22259. https://doi.org/10.1007/s11356-022-19321-x

IPCC. (2019). *2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories.*

Jo, Y., Lee, J., & Kim, H. (2016). Comparison of models for estimating methane emission factor for enteric fermentation of growing-finishing Hanwoo steers. *SpringerPlus, 5,* 1813. https://doi.org/10.1186/s40064-016-2889-7

Karimi-Zindashty, Y., VanderZaag, A. C., & Wagner-Riddle, C. (2011). Sources of uncertainty in the IPCC Tier 2 Canadian livestock model. *The Journal of Agricultural Science, 149*(6), 621–632. https://doi.org/10.1017/S002185961100092X

Kholod, N., Evans, M., Pilcher, R. C., Roshchanka, V., Ruiz, F., Coté, M., & Collings, R. (2020). Global methane emissions from coal mining to continue growing even with declining coal production. *Journal of Cleaner Production*, *256*, 120489.

Kouazounde, J. B., Djenontin, J. A., & Koura, I. B. (2015). Development of methane emission factors for enteric fermentation in cattle from Benin using IPCC Tier 2 methodology. *Animal, 9*(3), 526–533. https://doi.org/10.1017/S1751731114002626

Li, X., Wang, Y., & Zhang, J. (2019). Coal mining emissions and environmental management: A review. *Journal of Cleaner Production, 230,* 1223–1236. https://doi.org/10.1016/j.jclepro.2019.05.045

Pinem, S., Saragih, A. K., & Rachman, A. (2020). Estimating GHG emission level from oil and gas offshore production facility. *E3S Web of Conferences, 202,* 09004. https://doi.org/10.1051/e3sconf/202020209004

Putra, R., Nugroho, T., & Wijaya, H. (2022). Sustainable coal mining practices in Southeast Asia: A case study of Indonesia. *Resources Policy, 78,* 102850. https://doi.org/10.1016/j.resourpol.2022.102850

Santoso, P., Rahman, F., & Hidayat, A. (2014). Coal production trends and environmental impact in East Kalimantan, Indonesia. *Energy Policy, 74,* 31–39. https://doi.org/10.1016/j.enpol.2014.08.003

Sharma, R., & Kumar, S. (2020). Greenhouse gas emissions from coal mining: Assessment and mitigation strategies. *International Journal of Coal Science & Technology, 7*(4), 537–550. https://doi.org/10.1007/s40789-020-00305-2

Sun, Y., Liu, X., & Chen, H. (2023). Life-cycle assessment of coal mining emissions and environmental management strategies. *Journal of Environmental Management, 334,* 117450. https://doi.org/10.1016/j.jenvman.2023.117450

Wahyudi, D., Nugrahani, D., & Prasetyo, B. (2018). Production growth and feasibility study updates in Indonesian coal mining companies. *Resources Policy, 59,* 292–301.

https://doi.org/10.1016/j.resourpol.2018.07.010

Wang, K., Zhang, J., Cai, B., & Yu, S. (2019). Emission factors of fugitive methane from underground coal mines in China: Estimation and uncertainty. *Applied Energy*, *250*, 273–282.