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EVALUATING METHANE EMISSION QUANTIFICATION STRATEGIES FOR DECARBONIZATION IN UPSTREAM OIL AND GAS BASED ON THE OGMP 2.0 FRAMEWORK: A DECISION MAKING ANALYSIS AT PT BLUE ENERGI

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Abstract

Methane is a potent greenhouse gas with a global warming potential more than 80 times that of carbon dioxide over a 20-year horizon, making methane mitigation a priority for near-term decarbonization in the oil and gas industry. PT Blue Energi, an Indonesian upstream operator, joined the Oil and Gas Methane Partnership (OGMP) 2.0 in 2025 and targets the Level 5 Gold Standard, which requires a transition from emission-factor reporting (Levels 2-3) to source-level quantification (Level 4) and reconciled site-level measurement (Level 5). This study evaluates methane quantification strategies through a mixed-methods design combining qualitative situational analysis (SWOT and Kepner-Tregoe) with the Analytic Hierarchy Process (AHP). Pairwise-comparison data from ten subject-matter experts were aggregated by geometric mean, with priority weights derived from the principal eigenvector and consistency verified for every matrix. The results are source- and level-specific: at Level 4, Quantitative Optical Gas Imaging (QOGI) ranked first for fugitives (34.7%), process simulation using UniSim for flares (35.1%), and engineering calculation with QOGI for venting (40.1%); at Level 5, drone survey ranked highest (35.3%). All matrices satisfied the consistency requirement ($CR < 0.10$) and rankings were robust under sensitivity analysis, offering PT Blue Energi a replicable, expert-based framework for measurement-based methane reporting.

Keywords: Analytic Hierarchy Process; Decarbonization; Methane Quantification; Multi-Criteria Decision Analysis; OGMP 2.0.

INTRODUCTION

Methane is the second most important anthropogenic greenhouse gas after carbon dioxide and is recognised as a powerful short-lived climate forcer, with a global warming potential more than 80 times greater than carbon dioxide over a 20-year horizon (IPCC, 2021). Because of this high near-term radiative potency and methane's short atmospheric lifetime of roughly twelve years, reducing methane emissions has become one of the most effective and rapid strategies for limiting near-term warming and supporting the global transition toward net zero. The oil and gas industry is one of the largest and most readily addressable anthropogenic methane sources, and the International Energy Agency estimates that around 70 to 75 percent of these emissions could be abated with currently available measures, often at low or negative net cost because the captured methane is itself a saleable product (IEA, 2024).

Growing pressure from investors, lenders, and regulators has elevated expectations for measurement-based methane reporting, particularly through the Oil and Gas Methane Partnership 2.0 (OGMP 2.0) framework convened under the United Nations Environment Programme. OGMP 2.0 establishes a five-level reporting maturity ladder and encourages companies to progress from generic emission-factor estimates toward source-level quantification (Level 4) and site-level measurement with reconciliation between bottom-up and top-down estimates (Level 5), thereby improving inventory accuracy and transparency (UNEP, 2023). PT Blue Energi, one of Indonesia's leading publicly listed energy companies, formally joined OGMP 2.0 in 2025 and aims to attain the Level 5 Gold Standard, the highest reporting tier within the framework. Despite ongoing methane management initiatives, PT Blue Energi's current quantification practices remain limited to OGMP 2.0 Level 2 and Level 3, relying on IOGP and API Compendium emission categories and generic emission factors. A gap therefore exists between the company's current reporting capabilities and the measurement-based framework required to meet the Level 5 Gold Standard. A portfolio-level materiality assessment identified the Domestic Oil & Gas Offshore asset as the largest contributor (approximately 44% of total methane emissions), followed by Domestic Oil & Gas Onshore (27%), Domestic Oil Onshore (14%), and the International Asset A (10%); collectively these represent about 95% of the company's inventory. At the asset level, fugitive emissions are the dominant source, reaching approximately 72% of total methane emissions in offshore facilities. The absence of a structured decision-making framework creates uncertainty in determining the most appropriate Level 4 and Level 5 quantification strategies across a diverse portfolio of onshore, offshore, and international assets.

To address this gap, the study is guided by two research questions: (1) what decision-making framework and evaluation criteria are required to assess methane emission quantification strategies for Level 4 source-level quantification and Level 5 site-level measurement in accordance with OGMP 2.0 requirements; and (2) which Level 4 and Level 5 quantification alternatives are the most suitable for supporting decarbonization and meeting OGMP 2.0 reporting at PT Blue Energi. Accordingly, the objectives are to develop the decision framework and evaluation criteria, and to evaluate and determine the most suitable quantification alternatives for each emission source and reporting level.

LITERATURE REVIEW

Methane emission management in upstream oil and gas refers to the systematic process of identifying, quantifying, monitoring, reporting, and mitigating methane emissions across exploration, production, and processing activities. Within upstream operations, emissions originate from a heterogeneous set of sources including fugitive leaks from valves, flanges, and connectors; intentional venting; incomplete combustion during flaring; pneumatic devices; storage tanks; and abnormal operating conditions. A defining feature of these emissions is their highly skewed distribution, in which a small population of super-emitters contributes a disproportionate share of the total, with important implications for how monitoring should be prioritised (Alvarez et al., 2018). Independent aircraft- and satellite-based campaigns have repeatedly found that actual emissions exceed conventional bottom-up inventories, often by 50 to 100 percent, underscoring the importance of measurement-based quantification (Sherwin et al., 2024).

Modern programmes increasingly rely on a tiered combination of measurement technologies operating at different spatial scales. Close-range methods such as Quantitative Optical Gas Imaging (QOGI) and handheld sniffers are well suited to component-level leak localisation and repair, whereas screening platforms such as continuous fixed sensors, drones, aircraft-mounted spectrometers, and satellites enable rapid site-level and regional detection of large emitters (Fox et al., 2019). Satellite remote sensing has advanced rapidly, spanning wide-area mappers that constrain regional budgets and fine-resolution point-source imagers capable of attributing plumes to individual facilities (Jacob et al., 2022). Integrating these complementary technologies allows operators to reconcile top-down and bottom-up estimates and to target the high-emitting sources that dominate total emissions.

The OGMP 2.0 framework, convened under UNEP's International Methane Emissions Observatory, provides a global standard for measurement-based methane reporting. It defines a five-level reporting ladder and expects companies to progressively achieve Level 4 or Level 5 reporting for all material assets within three years for operated assets and five years for non-operated assets, supported by materiality analysis and a structured implementation plan (UNEP, 2020). Benchmarking against leading operators such as Eni, BP, and Shell shows that effective programmes combine periodic LDAR campaigns with optical, drone, and satellite-based detection, and rest on four pillars: robust governance, accurate and increasingly direct measurement, transparent and verifiable reporting, and proactive, prioritised mitigation.

To support structured selection among competing strategies, this study draws on three established analytical tools. SWOT analysis assesses the internal strengths and weaknesses and external opportunities and threats relevant to adopting Level 4 and Level 5 quantification. The Kepner-Tregoe method provides a systematic problem analysis that separates relevant information from noise and diagnoses the root causes preventing progression beyond Level 3. The Analytic Hierarchy Process (AHP), developed by Saaty (2004), decomposes a complex decision into a hierarchy of criteria and alternatives, derives priority weights from pairwise comparisons using the principal eigenvector, and verifies the reliability of expert judgements through a consistency ratio.

METHOD

This study employed a mixed-methods design that integrates qualitative situational analysis with quantitative multi-criteria decision analysis. The research proceeded from problem definition and formulation of the research questions, through a literature review and conceptual framework, to data collection, situational analysis, strategy formulation, decision-making analysis, sensitivity analysis, and finally a strategic solution and implementation plan. The qualitative stage used SWOT analysis to evaluate PT Blue Energi's internal and external position and the Kepner-Tregoe method to diagnose the root causes of the reporting gap, while the quantitative stage applied AHP to evaluate and prioritise the candidate strategies.

Primary data were obtained through semi-structured interviews and pairwise-comparison questionnaires. Interviews with five subject-matter experts (SMEs) from Corporate and Asset HSE, Facilities Engineering, and Technology Specialist functions, each with substantial industry experience, were used to confirm the business problem and to establish the evaluation criteria and the candidate methods. The pairwise-comparison questionnaire, based on the Saaty 1-9 fundamental scale, was distributed to ten respondents involved in the decision-making process, selected through purposive and snowball sampling (Patton, 2002; Biernacki & Waldorf, 1981). Secondary data were drawn from company documents, methane emission reports, and external literature. Data collection was conducted during 2025-2026 across the company's material upstream assets.

In the AHP procedure, the individual judgments were aggregated using the geometric mean method to form a consensus matrix, in line with Saaty's recommendation for group decision making. Priority weights were derived from the principal eigenvector of each pairwise comparison matrix, and the consistency of the judgments was verified by computing the Consistency Index (CI) and the Consistency Ratio (CR = CI/RI), where RI is the random index. A matrix was accepted as consistent when $CR < 0.10$. Because the decision was structured in two levels, the analysis first derived the criteria weights for each level, then evaluated the candidate methods for each Level 4 emission source (fugitive, flare, and venting) and the four site-level strategies for Level 5, before synthesising the overall recommendation.

Finally, a one-at-a-time (OAT) sensitivity analysis was performed to test the robustness of the rankings. The weight of each leading criterion was increased and decreased by 20% in turn, while the remaining weights were proportionally rescaled so that the complete set continued to sum to unity. The global priority score of each alternative was then recalculated and compared with the baseline result to determine whether the recommended alternative remained stable under different weighting scenarios.

RESULTS AND DISCUSSION

Situational Analysis and Criteria Definition

The SWOT analysis indicated that PT Blue Energi approaches Level 4 and Level 5 implementation from a position of organisational readiness, with strong corporate commitment to methane reduction, most assets already at Level 3 maturity, and existing QOGI pilot projects. External opportunities include the rapid maturation and falling cost of measurement technologies and rising investor expectations on methane transparency, while threats include the technical complexity and cost of reconciliation and evolving regulatory requirements. The Kepner-Tregoe problem analysis identified the root causes preventing progression beyond Level 2-3, namely a new and more stringent reporting requirement, limited Level 4 and Level 5 implementation experience, portfolio diversity and legacy infrastructure, and data-quality and instrumentation limitations.

Three themes emerged from the SME interviews: the company's current quantification still relies on generic emission factors with no structured decision framework; the most appropriate quantification method differs markedly by emission source; and the experts converged on a common set of evaluation criteria and candidate methods. Based on aggregated expert judgement, four criteria were selected for Level 4 (quantification performance, cost effectiveness, deployment feasibility & technology maturity, and HSE & operational risk) and a fifth criterion, reconciliation suitability & source completeness, was added for Level 5, reflecting the defining requirement to reconcile an independent top-down total against the bottom-up Level 4 inventory.

Analysis of Criteria Weights

The aggregated pairwise comparisons produced the normalized priority weights shown in Table 1 and Table 2. For Level 4, HSE & Operational Risk was the most important criterion (28.1%), reflecting the emphasis on minimising personnel exposure during recurring surveys around live hydrocarbon facilities, followed by Cost Effectiveness (25.3%), Deployment Feasibility & Technology Maturity (23.9%), and Quantification Performance (22.7%). The Level 4 criteria matrix was highly consistent (CR = 0.012). For Level 5, HSE & Operational Risk again ranked first (25.4%), followed by Cost Effectiveness (21.1%), Deployment Feasibility & Technology Maturity (19.8%), Measurement Performance (17.7%), and Reconciliation Suitability & Source Completeness (16.0%), with CR = 0.006.

Table 1. Normalized Priority Weights of the Criteria - Level 4 (Source-Level)

Criterion	Priority Weight	Rank
HSE & Operational Risk	0.281 (28.1%)	1
Cost Effectiveness	0.253 (25.3%)	2
Deployment Feasibility & Technology Maturity	0.239 (23.9%)	3
Quantification Performance	0.227 (22.7%)	4

Table 2. Normalized Priority Weights of the Criteria - Level 5 (Site-Level)

Criterion	Priority Weight	Rank
HSE & Operational Risk	0.254 (25.4%)	1
Cost Effectiveness	0.211 (21.1%)	2
Deployment Feasibility & Technology Maturity	0.198 (19.8%)	3
Measurement Performance	0.177 (17.7%)	4
Reconciliation Suitability & Source Completeness	0.160 (16.0%)	5

Analysis of Alternatives

Using the aggregated criteria weights, the candidate methods were compared pairwise under each criterion and synthesized into final priority weights. Because the Level 4 decision is source-specific, separate rankings were produced for fugitive, flare, and venting emissions (Tables 3 to 5), and the Level 5 site-level ranking is presented in Table 6. For fugitive emissions, the dominant category across the portfolio, Quantitative Optical Gas Imaging (QOGI) ranked first (34.7%), preferred under every criterion through its non-contact stand-off measurement, strong deployment feasibility, and competitive performance and cost. For flares, process simulation using UniSim ranked first (35.1%), avoiding the capital cost and shutdown burden of installing metering hardware. For venting, engineering calculation combined with QOGI ranked first (40.1%), offering the best balance of cost, feasibility, and HSE and operational risk for the distributed venting sources typical of upstream operations. All Level 4 matrices satisfied the consistency requirement (CR < 0.10).

Table 3. Final Priority Weights of Alternatives - Level 4 Fugitive Emissions

Alternative (Fugitive)	Priority Weight	Rank
QOGI (Quantitative Optical Gas Imaging)	0.347 (34.7%)	1
HFS (High-Flow Sampler)	0.341 (34.1%)	2
FID (Flame-Ionisation Detector)	0.312 (31.2%)	3

Table 4. Final Priority Weights of Alternatives - Level 4 Flare

Alternative (Flare)	Priority Weight	Rank
UniSim (Process Simulation)	0.351 (35.1%)	1
VISR (Optical Method)	0.328 (32.8%)	2
Continuous Flare Monitoring System (Flare IQ)	0.321 (32.1%)	3

Table 5. Final Priority Weights of Alternatives - Level 4 Venting

Alternative (Venting)	Priority Weight	Rank
Engineering Calculation + QOGI	0.401 (40.1%)	1
HFS (High-Flow Sampler)	0.300 (30.0%)	2
Direct Flowmeter	0.298 (29.8%)	3

For the Level 5 site-level decision, the four independent strategies were compared under the five criteria and synthesized into the final priority weights shown in Table 6. The drone ranked highest (35.3%), leading on measurement performance and reconciliation suitability by providing close-range, facility-level flux that can be reconciled against the Level 4 inventory at a cost compatible with the company's representative-field sampling budget. Satellite observation ranked second (31.5%), reflecting its cost effectiveness, low safety exposure, and wide-area screening capability, ahead of aircraft survey (18.7%) and the continuous monitoring system (14.5%). All Level 5 matrices satisfied the consistency requirement (CR < 0.10).

Table 6. Final Priority Weights of Alternatives - Level 5 Site-Level Strategy

Alternative (Site-Level)	Priority Weight	Rank
Drone Survey (TDLAS)	0.353 (35.3%)	1
Satellite Observation	0.315 (31.5%)	2
Aircraft Survey	0.187 (18.7%)	3
Continuous Monitoring System (CMS)/ Fixed Sensors	0.145 (14.5%)	4

Combining the criteria weights with the method performance scores yields the overall set of preferred strategies summarized in Table 7. The analysis identifies a source-specific Level 4 selection together with a drone-led Level 5 site-level strategy, rather than a single uniform methodology applied across all assets and sources.

Table 7. Overall Ranking of Methane Quantification Strategies

Decision	Preferred Strategy (Score)	Runner-up (Score)
Level 4 - Fugitive	QOGI (0.347)	HFS (0.341)
Level 4 - Flare	Process Simulation, UniSim (0.351)	VISR (0.328)
Level 4 - Venting	Eng. Calc. + QOGI (0.401)	HFS (0.300)
Level 5 - Site-level	Drone (0.353)	Satellite (0.315)

Sensitivity Analysis

The sensitivity analysis demonstrated that the decisions obtained from the AHP model are stable and reliable. A plus or minus 20% change in any single criterion weight, a substantial variation given that the weights themselves differ by only a few percentage points, did not alter the recommended alternative for any of the four decisions. QOGI for fugitive emissions, UniSim for flares, engineering calculation with QOGI for venting, and the drone for the site-level strategy were therefore insensitive to reasonable uncertainty in the expert judgements. The only instability observed concerned the near-tie between the High-Flow Sampler and the Direct Flowmeter at the second and third positions of the venting decision, separated by a negligible margin; because the recommended option is unaffected, the practical conclusion is unchanged. Overall, the rankings can be considered robust and suitable as a basis for the methane measurement strategy recommendations.

Implementation Plan

Effective implementation requires a phased action plan addressing technical, operational, regulatory, and financial dimensions, aligned with the OGMP 2.0 reporting timeline and the corporate target of a 37% absolute methane reduction by 2030 against a 2019 baseline. The proposed roadmap, summarised in Table 8, begins with setup and preparation, proceeds to Level 4 implementation at representative fields, and advances to Level 5 implementation with bottom-up Level 4 reporting, and culminates in reconciled site-level (Level 5) reporting. Consistent with the company’s plan to measure one representative field per asset group each year, the programme is designed to fall within a budget of approximately USD 100,000–150,000 per field, avoiding the higher per-site capital expenditure of installing continuous monitoring across every facility and keeping the representative-field sampling approach affordable and scalable.

Table 8. Phased Implementation Roadmap

Phase	Key Activities	Outcome
Phase 1: Setup & Preparation (2026)	Prepare detailed execution plan for Level 4 methods; select drone (site-level) providers; define representative fields; establish measurement, QA/QC and reconciliation protocols; secure HSE permits; submit implementation plan to OGMP.	Ensure technical, regulatory, and budget fit before deployment.
Phase 2: Level 4 Implementation (2026)	Implement selected Level 4 methods at a representative field: QOGI surveys for fugitives, process simulation or engineering calculation for flaring and venting, supported by QOGI.	Validate performance and the reconciliation process at field level.
Phase 3: Level 5 Implementation & Level 4 Reporting (2027)	Implement the selected drone-led Level 5 survey across asset groups (one representative field per asset materiality); submit bottom-up source Level 4 reporting.	Track progress against the OGMP 2.0 framework toward Gold Standard.
Phase 4: Level 5 Reporting (2028)	Evaluate and submit site-level measurement reconciliation reporting based on the previous year's data, reconciling the independent top-down total against the bottom-up Level 4 inventory.	Achieve reconciled Level 5 reporting toward the Gold Standard and track progress against the 37%-by-2030 target.

CONCLUSION

This study evaluated methane emission quantification strategies for PT Blue Energi's upstream assets in support of decarbonization and progression toward the OGMP 2.0 Gold Standard, using a decision-making analysis built on the Analytic Hierarchy Process and integrated with SWOT and Kepner-Tregoe situational analysis and expert interviews. In answer to the first research question, the decision framework comprises four criteria for Level 4 source-level quantification, in order of priority HSE & operational risk, cost effectiveness, deployment feasibility & technology maturity, and quantification performance, and five criteria for Level 5 site-level measurement, which add reconciliation suitability & source completeness, with HSE & operational risk and cost effectiveness again the most important.

In answer to the second research question, the most suitable strategies are source- and level-specific rather than a single uniform technology: at Level 4, QOGI for fugitive emissions, process simulation using UniSim for flares, and engineering calculation combined with QOGI for venting; and at Level 5, the drone as the independent site-level measurement strategy, reflecting its ability to obtain close-range, facility-level flux that can be reconciled against the Level 4 inventory. All pairwise comparison matrices satisfied the consistency requirement ($CR < 0.10$), and the rankings were robust under sensitivity analysis, supporting the reliability of the expert-based prioritization. A phased implementation roadmap aligns the programme with the OGMP 2.0 reporting timeline and the corporate target of a 37% absolute methane reduction by 2030. It is recommended that PT Blue Energi deploy the preferred strategies by level and source beginning with the highest-materiality assets; build reconciliation and data-quality capability, including formal uncertainty quantification, as the core enabler of the Level 5 Gold Standard; adopt a phased, representative-field roll-out; strengthen vendor and regulatory engagement; and embed the measurement programme within capital and ESG planning. The study is limited by its reliance on the judgments of ten experts within a single company and by the use of representative planning figures rather than completed field campaigns. Future research could expand and diversify the respondent panel, validate the selected strategies through actual field measurement and reconciliation, incorporate a marginal abatement cost analysis, and extend the framework to a multi-period evaluation as measurement technologies and OGMP guidance continue to evolve. By using a transparent, expert-based decision method, the research strengthens the governance dimension of the company's ESG performance and provides a replicable framework for other upstream operators.

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