ACCSCIENCE PUBLISHING

Asian Journal of Water, Environment and Pollution

ORIGINAL RESEARCH ARTICLE

Developing a subsector-specific ESG materiality framework with standards alignment: Evidence from India's natural gas sector

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Abstract

India's natural gas sector is pivotal to energy security and economic growth, yet faces increasing pressure to align with Environmental, Social, and Governance (ESG) principles amid the nation's low-carbon transition. This study develops and evaluates subsector-specific ESG materiality frameworks, integrating perspectives from internal stakeholders (e.g., employees with experience or knowledge of sustainability/ESG and at different hierarchical levels) and external stakeholders (e.g., regulators, non-governmental organizations, suppliers, and customers) through surveys and expert interviews. Materiality matrices from gas sector segments (i.e., upstream, midstream, downstream, and integrated operations) highlight greenhouse gas emissions, water management, and stakeholder engagement as priorities, with sectoral differences: upstream activities focus on emissions, whereas downstream operations emphasize energy efficiency—identified using Kruskal–Wallis tests (e.g., p = 0.014 for greenhouse gas emissions). Correlation analyses revealed strong links, such as between emissions and low-carbon strategies (τ = 0.58–0.65), guiding materiality prioritization. Alignment with global standards (e.g., Global Reporting Initiative, Sustainability Accounting Standards Board, International Petroleum Industry Environmental Conservation Association) and India's Business Responsibility and Sustainability Reporting framework was robust for environmental factors but weak in biodiversity (16.7%), supply chain sustainability (25%), and Sustainable Development Goals 5 (gender equality) and 14 (life below water). These gaps highlight opportunities for tailored ESG strategies. Recommendations include collaborative platforms, advanced analytics, and regulatory incentives to enhance compliance and address stakeholder expectations. The framework provides a strategic guide for sustainable practices, strengthening the sector's resilience and supporting India's sustainable energy future.

Keywords: Natural gas; Carbon; Sustainable development; Renewable energy; Stakeholders

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Citation: Sarkar S, Nair MMS, Datta A, Singh V, Maurya S, Rathore J. Developing a subsector-specific ESG materiality framework with standards alignment: Evidence from India's natural gas sector. *Asian J Water Environ Pollut.* 2026;23(3):025520397. doi: 10.36922/AJWEP025520397

Received: December 26, 2025

Revised: February 6, 2026

Accepted: February 10, 2026

Published online: April 13, 2026

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1. Introduction

The Indian oil and natural gas sector is a cornerstone of the nation's energy security, economic growth, and industrial progress. As India pivots toward a low-carbon economy, Environmental, Social, and Governance (ESG) principles have become critical for ensuring corporate responsibility and strategic resilience.[1] Rising scrutiny from stakeholders, regulators, investors, and civil society demands greater transparency, sustainability, and ethical governance in fossil fuel industries.[2] Materiality assessment, which identifies and prioritizes ESG issues based on operational risks and stakeholder expectations, is pivotal to this integration.[3] While global frameworks such as the Global Reporting Initiative (GRI), Sustainability Accounting Standards Board (SASB), and International Petroleum Industry Environmental Conservation Association (IPIECA) provide standardized guidance, the Securities and Exchange Board of India's Business Responsibility and Sustainability Reporting (BRSR) framework seeks to localize ESG reporting, yet adoption in the gas sector remains inconsistent.[4]

The Indian gas sector, spanning upstream, midstream, downstream, and integrated operations, faces distinct ESG challenges. Upstream activities grapple with emissions-intensive exploration, while downstream operations focus on energy efficiency and consumer safety.[5] These variations, often overlooked in corporate disclosures, necessitate subsector-specific ESG strategies.[6] Moreover, internal stakeholders (e.g., employees with experience or knowledge of sustainability/ESG and at different hierarchical levels) prioritize governance and risk, while external stakeholders (e.g., regulators, non-governmental organizations [NGOs], suppliers, and customers) emphasize environmental compliance and social equity, highlighting the need for a double materiality approach[3] (hereafter, referred to as "internal and external stakeholders" for brevity).

This study aims to develop and evaluate subsector-specific ESG materiality frameworks for the Indian natural gas sector, integrating stakeholder perspectives to prioritize key issues and assess alignment with global and Indian ESG standards. Using stakeholder surveys, statistical analyses (e.g., Kruskal–Wallis tests, correlation analyses), and alignment heatmaps, the research identifies material ESG topics, sectoral differences, and compliance gaps. The findings seek to guide corporate leaders, policymakers, and ESG practitioners in crafting targeted sustainability strategies, enhancing regulatory alignment, and bolstering India's energy transition.

2. Literature review

The adoption of ESG frameworks has become central to corporate strategies, particularly in the energy sector, due to rising stakeholder expectations and regulatory demands.[7] Globally, sustainability reporting is now widespread among major corporations, with approximately 96% of the largest global firms publishing ESG disclosures.[7] This shift toward transparency has intensified interest in double materiality, which evaluates both financial impacts on businesses and their broader socioenvironmental impacts.[8] Recent regulations, such as the European Union's Corporate Sustainability Reporting Directive, have accelerated the adoption of double materiality frameworks.[8]

The deepening climate crisis has elevated the importance of net-zero commitments, with global and Indian companies, including those in the carbon-intensive natural gas sector, announcing plans to achieve net-zero emissions by 2050. These plans necessitate strategic shifts in operations and production, emphasizing executive-level leadership, science-based long-term targets, and sustainable finance mechanisms such as green bonds, carbon credits, battery energy storage, and carbon capture, utilization, and storage. While afforestation, renewable energy, and energy transitions are widely adopted, studies highlight the need for enhanced target-setting and implementation to align with ESG frameworks like GRI and India's BRSR, addressing gaps in biodiversity and supply chain sustainability to support India's net-zero goals.[9]

India has significantly advanced its ESG reporting through the Securities and Exchange Board of India's mandatory BRSR[4], implemented from fiscal year 2022–2023. BRSR includes comprehensive ESG indicators aligning with global frameworks such as the GRI and the Task Force on Climate-related Financial Disclosures.[10] Recent enhancements such as BRSR Core and mandatory reporting of Scope 3 emissions have further bolstered this framework, emphasizing assurance requirements and transparency in the value chain.[11,12] These developments underscore India's alignment with global best practices while integrating localized requirements such as reporting on key suppliers and customers.[11]

Subsector-specific ESG reporting frameworks have become essential due to operational differences across industries. The gas sector, in particular, faces unique ESG challenges, including significant emissions and environmental impacts. Consequently, organizations like IPIECA have developed specialized ESG reporting guidelines widely adopted by the industry[13]. For instance, approximately 83% of gas companies utilize the IPIECA/

American Petroleum Institute/International Association of Oil and Gas Producers framework for ESG disclosures, reflecting subsector-specific metrics on climate, environmental management, and social performance.[13]

Despite advancements, challenges remain. Studies from 2025 highlight significant variability and data quality issues in ESG disclosures, particularly within emerging economies, including India, where gas firms often lag behind other sectors in transparency and comprehensive reporting.[14] Additionally, inconsistencies in reporting methodologies and data collection complicate benchmarking and comparability across firms, undermining stakeholder trust and effective ESG integration.[15]

A review of the literature on India's energy sector indicates that transparency is increasing; however, there are still significant structural deficiencies (Table S1). For example, environmental reporting places a high priority on carbon intensity[16], while efforts toward standardization remain challenging.[17] On the other hand, biodiversity impact assessments are often less detailed when using traditional ecological models.[18,19] Many social strategies are not aligned with the United Nations Sustainable Development Goals (SDGs), such as gender equality.[20] In terms of governance, the majority of governance mechanisms rely more heavily on human factors (e.g., leadership characteristics)[21], whereas less emphasis is placed on the resilience of institutions.[22] The challenges mentioned above occur concurrently with the inherent trade-offs associated with energy security[23], the move to mandatory reporting requirements[24], and the risk of greenwashing.[25]

By addressing these gaps, this study aims to provide an extensive subsector-specific ESG materiality assessment tailored explicitly for the Indian gas sector. By aligning subsector-specific frameworks with evolving regulatory requirements, the research seeks to enhance ESG transparency, inform strategic decision-making, and facilitate the transition toward sustainable operations.

3. Materials and methods

3.1. Data collection

Data were collected via structured surveys and expert interviews with internal and external stakeholders. Additionally, purposive sampling was employed to select participants representing stakeholders in the Indian natural gas sector who possessed relevant expertise. Internal stakeholders (n = 12) comprised employees working at different hierarchical levels with expertise in sustainable development and/or ESG and were recruited through professional networks and referrals from their employers. External stakeholders (n = 5) included regulators, NGOs, suppliers, and customers, and were identified via industry associations and sector experts. This purposive approach placed a greater emphasis on depth of understanding than random selection, focusing on key informants who possess significant knowledge of ESG-related issues.

Inclusion criteria required participants to have at least one year of relevant experience in the gas sector and ESG (mean ExpGas = 13.08 years, ExpSus = 8.91 years for internals). Exclusion criteria excluded non-experts or those without consent. Observations were independent, as each respondent provided individual survey/interview responses without group influence. Among internal stakeholders, subsector representation included approximately three upstream, three midstream, four downstream, and two integrated firms (based on Q1Sect.Op self-reports). For externals, categories included one regulator, one NGO, two suppliers, and one customer; subsector ties were broader (e.g., regulators oversee all).

The variables for internal and external stakeholders in the study were derived from the structured questionnaire designed to capture specific ESG-related data points from respondents in the Indian natural gas sector. Each variable corresponds directly to a question or sub-question, such as Q1 for sector of operation (sector identification: Q1Sect.Op for sector of operation, categorical) or Q3–Q5 for rating environmental, social, and governance topics (e.g., Q3Env.Air, Q4Soc.Access, Q5Gov.Antcmp; Tables A1 and A2), with responses typically on a 1–5 Likert scale or binary/multiple-choice formats. For example, Q2 (stakeholder engagement methods: multiple-choice/binary selections generating variables) generates variables like Q2Mth.Stk (stakeholder engagement) based on the selected methods, while Q9 creates variables like Q9.Regu (regulatory standards) from factors influencing ESG assessments. These variables are systematically labelled to reflect their category and specific ESG aspect, facilitating statistical analysis and the development of materiality matrices.

The expert interviews were conducted with structured questionnaires. Surveys utilized Likert-scale responses to assess ESG factor significance and related metrics. For internal stakeholders, Q3–Q5 evaluated environmental, social, and governance factors (1–5 Likert scale, where 1 = not significant, 5 = highly significant), while Q8–Q14 assessed experience, engagement, and standards alignment (1–5 scale). For external stakeholders, questions Q1Env–Q3Gov rated ESG factor significance (1–5 scale), and Q5 questions (e.g., Q5.Regu, Q5.Stk, Q5.Sstn) evaluated standards alignment (1–2 scale, where 1 = aligned, 2 = not aligned).

Expert interviews supplemented survey data, with

responses quantified through Likert-scale equivalents for integration into materiality assessments. Surveys and expert interviews were conducted from January to August 2024, capturing perspectives amid India's evolving ESG regulations. The questionnaire was developed in January–February, followed by validation by three domain experts in February–March; April–May was used for revision into two separate questionnaires (internal/external) and pilot testing; May–August was used for interviews conducted via physical or virtual meetings (internals = 12, externals = 5).

While attempts were made to include diverse subsectors and stakeholder groups, the sub-group sizes are still small and uneven, especially for external stakeholders and specific operational areas. Therefore, statistical comparisons at the subsector level should be interpreted as exploratory.

3.2. Data preprocessing

Missing data in survey responses were handled using the missForest algorithm, implemented via the missForest package in the R software. This non-parametric method imputes missing values based on random forest models, ensuring data completeness without introducing significant bias. Data were cleaned to remove duplicates and inconsistencies, and categorical responses were encoded numerically for analysis.

3.3. Statistical analyses

Statistical analyses were conducted to evaluate stakeholder characteristics, ESG priorities, sectoral differences, and relationships among variables. Shapiro–Wilk tests assessed the normality of survey responses to determine appropriate statistical methods. The Shapiro–Wilk test assesses deviations from a normal distribution and was chosen for its sensitivity to small sample sizes (n = 17) in guiding parametric and non-parametric decisions. For non-normal data, Kruskal–Wallis tests evaluated differences in ESG factor significance across upstream, midstream, downstream, and integrated operations, with Dunn's post-hoc tests identifying specific sectoral contrasts. The Kruskal–Wallis test is a non-parametric alternative to ANOVA and does not require the assumption of normality to compare medians between multiple groups. Thus, it is suitable for our ordinal Likert-scale data to identify significant differences across sectors (e.g., upstream vs. midstream).

For normally distributed data, Pearson's correlation coefficient measured relationships between variables (e.g., experience in gas operations vs. sustainability expertise). Pearson's correlation coefficient measures linear relationships between normally distributed variables (e.g., experience), while Kendall's Tau is used when data do not meet the assumptions of normality and/or are ordinal, as Kendall's Tau is a rank-based method that is more robust for smaller samples when examining empirical relationships between ESG variables. Kendall's Tau correlations were used for non-normal data to explore associations (e.g., between greenhouse gas [GHG] emissions and low-carbon strategies). All tests used a significance level of $\alpha = 0.05$.

3.4. Materiality matrix development

Subsector-specific materiality matrices were constructed for upstream, midstream, downstream, and integrated operations by aggregating Likert-scale responses (1–5) from internal (Q3–Q5) and external (Q1Env–Q3Gov) surveys. Responses were averaged to derive scores for business significance (internal stakeholder perspective) and stakeholder significance (external stakeholder perspective). Internal (business significance) and external (stakeholder significance) inputs were weighted equally via simple averaging, as both perspectives are essential in a double materiality framework. These scores were plotted on two-dimensional matrices, with axes representing business and stakeholder significance, to identify priority ESG factors (e.g., GHG emissions, water management). External Q5 responses (1–2 scale) informed standards alignment analyses but were not included in the materiality matrices.

3.5. Standards alignment analysis

Alignment with global standards (e.g., GRI, SASB, IPIECA) and India's BRSR framework was assessed using cross-tabulation of survey responses, focusing on Q9 (internal) and Q5 (external) questions. Alignment percentages were calculated as the proportion of stakeholders indicating consistency between ESG factors and standards (e.g., Q9.Sstn, Q5.Sstn). Correlation matrices and heatmaps were used to visualize relationships between ESG factors and standards alignment.

3.6. Software

All analyses were performed in R (version 4.4.1, R Foundation for Statistical Computing, Austria) using the following packages: missForest for missing data imputation, ggplot2 for visualization (e.g., heatmaps, Pareto plots), dplyr for data manipulation, stats for statistical tests (e.g., Shapiro–Wilk, Kruskal–Wallis), and PMCMRplus for Dunn's post-hoc tests.[26-29] Visualizations were generated to support interpretation, including correlation heatmaps

and materiality matrices.

4. Results

This section presents the findings from the ESG materiality assessment for the Indian natural gas sector, based on structured surveys and expert interviews with internal and external stakeholders. The results are organized to reflect the development and evaluation of subsector-specific ESG materiality frameworks, covering descriptive statistics, normality tests, correlation analysis, materiality matrices for upstream, midstream, downstream, and integrated sectors, sectoral comparisons, and alignment with global (e.g., GRI, SASB, IPIECA) and Indian (e.g., BRSR) ESG standards. Analyses were conducted using R software, with findings summarized in the provided tables and figures.

4.1. Descriptive statistics

Descriptive statistics provide insights into stakeholder characteristics and ESG priorities (Tables 1–4). Internal stakeholders (ExpGas), averaging 13.08 years of gas industry experience (median = 13.00 years, range = 3–20 years) and 8.91 years in sustainability (ExpSus, median = 8.00 years, range = 1–25 years), demonstrated substantial expertise (Table 1). Materiality assessments (Q8.Freq) occurred approximately biennially (mean = 2.83, on a 1–5 scale).

Table 2 summarizes the nominal variables collected from internal stakeholders, capturing the presence or absence of specific ESG-related activities and stakeholder engagement practices within the Indian natural gas sector. The findings reveal that stakeholder engagement (Q2Mth.Stk) is widely practiced, with 10 out of 12 respondents confirming its use, followed closely by materiality matrices (Q2Mth. Matrix) and risk analyses (Q2Mth.Risk), each reported by eight respondents. Benchmarking (Q2Mth.Bench) and consultation (Q2Mth.Cnslt) were less common, with only five respondents indicating their application, while other methods (Q2Mth.Other) were rarely used (n = 1).

For stakeholder engagement (Q7 variables), internal groups such as employees (Q7.Int.Emp, n = 11) and management (Q7.Int.Mng, n = 12) were consistently involved, whereas external stakeholders like partners (Q7. Ext.Partner, n = 11) and customers (Q7.Ext.Cust, n = 10) were frequently engaged, compared with media (Q7.Ext. Media, n = 2) or other external groups (Q7.Ext.Other, n = 1). Alignment with ESG standards (Q9 variables) indicated strong consideration of sustainability (Q9.Sstn, n = 8) and ESG frameworks (Q9.ESG, n = 7), but other drivers like financial considerations (Q9.Fin, n = 3) were less prioritized.

Stakeholder engagement (Q2Mth.Stk) was prevalent (83.3%), followed by materiality matrices (Q2Mth.Matrix, 66.7%) and risk analyses (Q2Mth.Risk, 66.7%), with benchmarking less common (Q2Mth.Bench, 41.7%). Engagement (Q7) was near-universal (91.7–100%), involving partners (91.7%), customers (83.3%), and regulators (75%).

Governance engagement (Q11.Eng.Level, mean = 3.75), risk integration (Q13.Risk, mean = 3.67), and ESG impact (Q14.Impact, mean = 4.08) indicated moderate to high levels of engagement on a 1–5 scale ; these mean-based descriptive statistics were derived directly from the survey dataset. Table 3 reports only the frequency distribution of ordinal responses. Respondents were distributed across the natural gas sector segments as follows: for internal stakeholders (n = 12), 8.3% (n = 1) were from upstream, 25% (n = 3) from midstream, 25% (n = 3) from downstream, and 41.7% (n = 5) from integrated operations. For external stakeholders (n = 5), the distribution was broader but included perspectives relevant to all segments (e.g., regulators covering multiple areas).

Figure 1 shows the distribution of air quality ratings, with bars representing frequency and a cumulative line indicating percentage contribution. Most responses cluster around ratings 4 and 5, each reported four times. Lower ratings (3, 2, and 1) occur less frequently, with "3" reported twice, and "1" and "2" reported once each. The cumulative line increases sharply at ratings 4 and 5, reflecting their dominant share, and reaches 100% by rating 2. These results suggest that most respondents perceive air quality positively, with a few lower ratings.

Figure 2 shows that all external stakeholder responses are at rating 5, with no responses at lower ratings. The frequency bar peaks at rating 5, and the cumulative line rises immediately to 100%, indicating the unanimous highest ratings. This reflects a uniformly positive perception with no variation.

External stakeholders rated environmental factors highly, with air emissions (Q1Env.Air, mean = 5.0), GHG emissions (Q1Env.Grngs, mean = 4.8), and climate adaptation (Q1Env.Clmt, mean = 4.8) leading, while ecological impact (Q1Env.Eco, mean = 4.2) was lower. Social factors prioritized access to energy (Q2Soc. Access, mean = 5.0) and health and safety (Q2Soc.Health, mean = 4.8), with labor rights (Q2Soc.Labr, mean = 2.8) less emphasized. Governance factors highlighted energy security (Q3Gov.Enrg, mean = 5.0) and financial sustainability (Q3Gov.Finc, mean = 4.8) ; these mean-based descriptive statistics were derived directly from the survey dataset. Table 4 reports only the frequency distribution of ordinal responses. Pareto plots (Figures 1 and 2) confirmed the high frequencies for air emissions,

Table 1. Summary statistics of quantitative variables for internal stakeholders

Variable	Minimum	1st quartile	Median	Mean	3rd quartile	Maximum
ExpGas	3.00	10.00	13.00	13.08	18.00	20.00
ExpSus	1.00	4.00	8.00	8.91	12.50	25.00
Q8.Freq	1.00	1.75	3.00	2.83	4.00	5.00

Table 2. Summary statistics of nominal variables for internal stakeholders

Variable	Level 0	Level 1
Q2Mth.Stk	2	10
Q2Mth.Matrix	4	8
Q2Mth.Ref	4	8
Q2Mth.Risk	4	8
Q2Mth.Bench	7	5
Q2Mth.Review	8	4
Q2Mth.Cnslt	7	5
Q2Mth.Other	11	1
Q7.Int.Emp	1	11
Q7.Int.Mng	-	12
Q7.Int.Brdm	4	8
Q7.Int.Shr	8	4
Q7.Int.Oth	11	1
Q7.Ext.Shrh	9	3
Q7.Ext.Cust	2	10
Q7.Ext.Partner	1	11
Q7.Ext.Local	5	7
Q7.Ext.Reg	3	9
Q7.Ext.NGO	9	3
Q7.Ext.Inv	5	7
Q7.Ext.Inds	7	5
Q7.Ext.Media	10	2
Q7.Ext.Other	11	1
Q9.Regu	7	5
Q9.Stk	7	5
Q9.Sstn	4	8
Q9.Risk	5	7
Q9.Fin	9	3
Q9.Ind	8	4
Q9.ESG	5	7
Q9.Other	12	-

Table 3. Summary statistics of ordinal variables for internal stakeholders

Variable	Level 1	Level 2	Level 3	Level 4	Level 5
Q11.Eng.Level	0	1	5	2	4
Q13.Risk	0	0	5	6	1
Q14.Impact	0	0	2	7	3

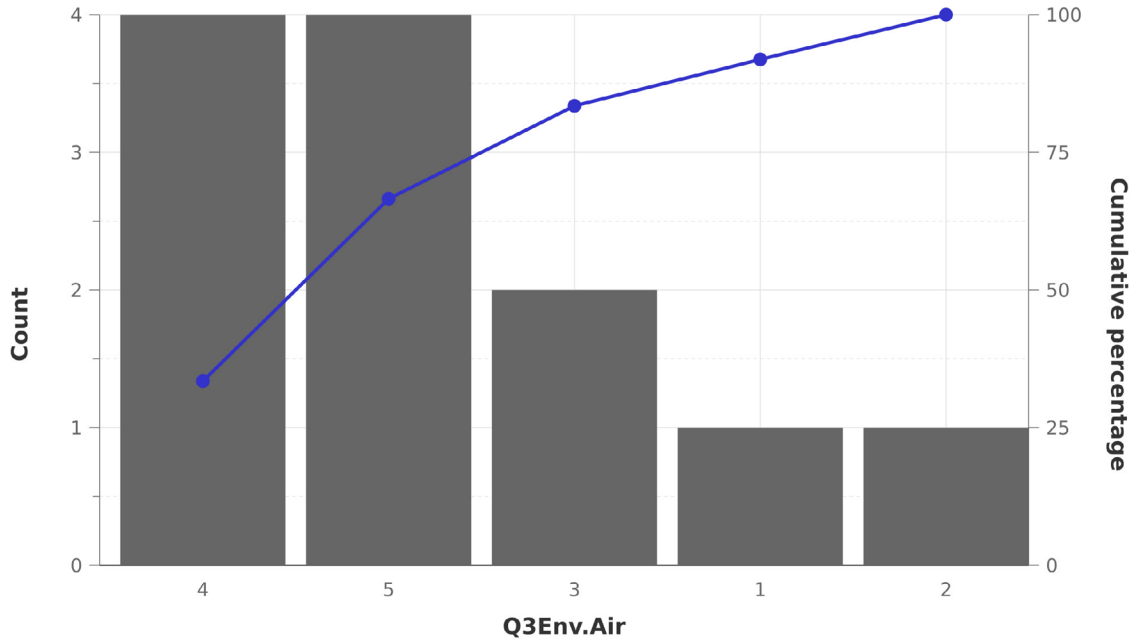

Figure 1. Pareto chart of internal stakeholder responses for perception of air quality (Q3Env.Air)

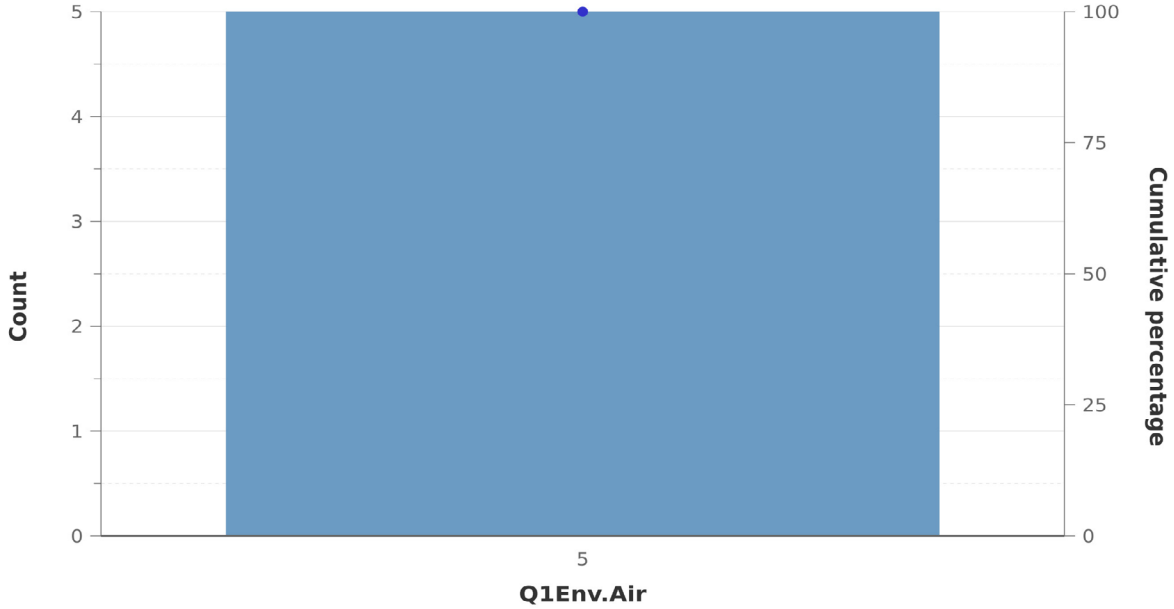

Figure 2. Pareto chart of external stakeholder responses for perception of air emissions (Q1Env.Air)

Table 4. Summary statistics of external stakeholder responses

Factor	Level 1	Level 2	Level 3	Level 4	Level 5
Q1Env.Air	0	0	0	0	5
Q1Env.Eco	0	0	0	3	2
Q1Env.Clmt	0	0	0	1	4
Q1Env.Rehab	0	1	1	2	1
Q1Env.Cir	0	1	2	1	1
Q1Env.Dis	0	0	1	1	3
Q1Env.Enrg	0	0	0	2	3
Q1Env.Env	0	0	0	1	4
Q1Env.Flar	0	0	0	2	3
Q1Env.Grngs	0	0	1	0	4
Q2Soc.Access	0	0	0	0	5
Q2Soc.Asset	0	0	1	2	2
Q2Soc.Cstmr	0	0	1	3	1
Q2Soc.Ecnmc	0	1	0	2	2
Q2Soc.Labr	2	0	0	2	1
Q2Soc.Frdm	1	0	3	1	0
Q2Soc.HmnCptl	0	1	0	3	1
Q2Soc.Hmnrts	0	0	1	2	2
Q2Soc.Land	0	0	1	3	1
Q2Soc.Lcl	0	0	0	3	2
Q2Soc.Equal	0	0	1	3	1
Q3Gov.Antcmp	0	0	1	4	0
Q3Gov.Antcrr	0	0	0	2	3
Q3Gov.Ethcs	0	0	0	3	2
Q3Gov.Cnfl	0	0	1	4	0
Q3Gov.Corp	0	0	0	3	2
Q3Gov.Cris	0	0	0	1	4
Q3Gov.Cyber	0	0	2	2	1
Q3Gov.Digit	0	0	2	3	0
Q3Gov.Enrg	0	0	0	0	5
Q3Gov.Finc	0	0	0	1	4
Q3Gov.Pay	0	0	0	3	2
Q3Gov.Plcy	0	0	0	3	2
Q3Gov.Suplchn	0	0	1	2	2
Q5.Regu	1	4	-	-	-
Q5.Stk	1	4	-	-	-
Q5.Sstn	1	4	-	-	-
Q5.Risk	2	3	-	-	-
Q5.Fin	1	4	-	-	-

(*Cont'd...*)

Table 4. *Continued*

Factor	Level 1	Level 2	Level 3	Level 4	Level 5
Q5.Ind	3	2	-	-	-
Q5.ESG	5	-	-	-	-
Q5.Other	5	-	-	-	-
Q6.Impact	0	1	2	1	1
Q8.Eff	0	0	2	2	1

Table 5. Results of Shapiro–Wilk tests for internal stakeholder variables

Variable	*p*-value	Normality
Q3Env.Air	0.057	Normal
Q3Env.Eco	0.078	Normal
Q3Env.Clmt	0.080	Normal
Q3Env.Rehab	0.139	Normal
Q3Env.Cir	0.010	Not normal
Q3Env.Dis	0.000	Not normal
Q4Soc.Asset	0.000	Not normal
Q3Env.Enrg	0.015	Not normal
Q3Env.Env	0.000	Not normal
Q3Env.Flar	0.003	Not normal
Q3Env.Grngs	0.000	Not normal
Q3Env.Lowc	0.009	Not normal
Q3Env.Matr	0.433	Normal
Q3Env.Spil	0.002	Not normal
Q3Env.Wtrmn	0.032	Not normal
Q3Env.Wstmn	0.012	Not normal
Q4Soc.Access	0.033	Not normal
Q4Soc.Cstmr	0.012	Not normal
Q4Soc.Ecnmc	0.029	Not normal
Q4Soc.Labr	0.034	Not normal
Q4Soc.Frdm	0.020	Not normal
Q4Soc.HmnCptl	0.123	Normal
Q4Soc.Hmnrts	0.280	Normal
Q4Soc.Land	0.026	Not normal
Q4Soc.Lcl	0.100	Normal
Q4Soc.Equal	0.200	Normal
Q4Soc.Health	0.000	Not normal
Q4Soc.Stw	0.082	Normal
Q4Soc.Suplr	0.440	Normal
Q5Gov.Antcmp	0.024	Not normal
Q5Gov.antcrr	0.001	Not normal
Q5Gov.Ethcs	0.001	Not normal

(*Cont'd...*)

Table 5. *Continued*

Variable	*p*-value	Normality
Q5Gov.Cnfl	0.064	Normal
Q5Gov.Corp	0.000	Not normal
Q5Gov.Cris	0.005	Not normal
Q5Gov.Cyber	0.033	Not normal
Q5Gov.Digit	0.011	Not normal
Q5Gov.Enrg	0.000	Not normal
Q5Gov.Finc	0.012	Not normal
Q5Gov.Pay	0.109	Normal
Q5Gov.Plcy	0.011	Not normal
Q5Gov.Suplchn	0.015	Not normal
Q5Gov.Stkmng	0.018	Not normal
Q11.Eng.Level	0.032	Not normal
Q13.Risk	0.006	Not normal
Q14.Impact	0.012	Not normal
ExpGas	0.252	Normal
ExpSus	0.133	Normal

access to energy, and stakeholder engagement.

4.2. Normality tests

Shapiro–Wilk tests identified normal distributions ($p > 0.05$) for internal stakeholder variables (Table 5), such as air quality (Q3Env.Air, $p = 0.057$), ecological impact (Q3Env.Eco, $p = 0.078$), and experience metrics (ExpGas, $p = 0.252$; ExpSus, $p = 0.133$), as well as external stakeholder variables (Table 6), including land rehabilitation (Q1Env.Rehab, $p = 0.814$) and human capital (Q2Soc.HmnCptl, $p = 0.135$). Additional normally distributed variables included low-carbon strategies (Q1Env.Lowc, $p = 0.314$) and supply chain governance (Q3Gov.Suplchn, $p = 0.314$).

Non-normal distributions ($p \leq 0.05$) included GHG emissions (Q3Env.Grngs, $p = 0.000$; Q1Env.Grngs, $p = 0.000$), health and safety (Q4Soc.Health, $p = 0.000$; Q2Soc.Health, $p = 0.000$), and corporate governance (Q5Gov.Corp, $p = 0.000$), justifying the use of non-parametric methods for these factors (Tables 5 and 6).

4.3. Correlation analysis

Correlation analyses revealed key relationships. For internal stakeholders, Pearson's correlation indicated a moderate positive link between gas and sustainability experience (ExpGas vs. ExpSus, $r = 0.52$, $p < 0.05$; Figure 3). Sectoral differences were identified by Kruskal–Wallis tests (e.g., $p = 0.014$ for GHG emissions, $H = 7.55$, df = 3), with upstream focusing on emissions and downstream on energy efficiency. The sectoral differences in GHG emissions were significant ($H = 7.55$, df = 3, $p = 0.014$), with a large effect size ($\eta^2 \approx 0.69$, indicating approximately 69% of variance explained by sector).

Dunn's post-hoc tests identified specific contrasts (e.g., upstream vs. downstream, adjusted $p < 0.05$), with multiple-comparison control via Bonferroni adjustment to maintain family-wise error rate. Kendall's Tau identified strong positive correlations, such as GHG emissions with low-carbon strategies (Q3Env.Grngs vs. Q3Env.Lowc, $\tau = 0.58$) and governance engagement with risk integration (Q11.Eng.Level vs. Q13.Risk, $\tau = 0.62$). A negative correlation was observed between health and safety and flaring (Q4Soc.Health vs. Q3Env.Flar, $\tau = -0.36$). These Kendall's Tau correlations represent strong effect sizes ($\tau > 0.5$ per Cohen's guidelines), indicating robust associations that guide materiality prioritization.

External stakeholders showed strong positive correlations between climate adaptation and GHG emissions (Q1Env.Clmt vs. Q1Env.Grngs, $\tau = 0.65$) and between equal opportunity and human capital (Q2Soc.Equal vs. Q2Soc.HmnCptl, $\tau = 0.58$), with a negative correlation between asset integrity and ecological impact (Q2Soc.Asset vs. Q1Env.Eco, $\tau = -0.52$). Heatmaps (Figures 3–7) visualized these patterns, supporting materiality assessment and prioritization.

4.4. Materiality matrices

Table 6. Results of Shapiro–Wilk tests for external stakeholder variables

Variable	*p*-value	Normality
Q1Env.Eco	0.006	Not normal
Q1Env.Clmt	0.000	Not normal
Q1Env.Rehab	0.814	Normal
Q3Env.Cir	0.814	Normal
Q1Env.Dis	0.046	Not normal
Q1Env.Enrg	0.006	Not normal
Q1Env.Env	0.000	Not normal
Q1Env.Flar	0.006	Not normal
Q1Env.Grngs	0.000	Not normal
Q1Env.Lowc	0.314	Normal
Q1Env.Matr	0.046	Not normal
Q1Env.Spil	0.046	Not normal
Q1Env.Wtrmn	0.325	Normal
Q1Env.Wstmn	0.046	Not normal
Q2Soc.Asset	0.314	Normal
Q2Soc.Cstmr	0.325	Normal
Q2Soc.Ecnmc	0.146	Normal
Q2Soc.Labr	0.111	Normal
Q2Soc.Frdm	0.135	Normal
Q2Soc.HmnCptl	0.135	Normal
Q2Soc.Hmnrts	0.314	Normal
Q2Soc.Land	0.325	Normal
Q2Soc.Lcl	0.006	Not normal
Q2Soc.Equal	0.325	Normal
Q2Soc.Health	0.000	Not normal
Q2Soc.Stw	0.000	Not normal
Q2Soc.Suplr	0.314	Normal
Q3Gov.Antcmp	0.000	Not normal
Q3Gov.antcrr	0.006	Not normal
Q3Gov.Ethcs	0.006	Not normal
Q3Gov.Cnfl	0.000	Not normal
Q3Gov.Corp	0.006	Not normal
Q3Gov.Cris	0.000	Not normal
Q3Gov.Cyber	0.314	Normal
Q3Gov.Digit	0.006	Not normal
Q3Gov.Finc	0.000	Not normal
Q3Gov.Pay	0.006	Not normal
Q3Gov.Plcy	0.006	Not normal
Q3Gov.Suplchn	0.314	Normal
Q3Gov.Stkmng	0.314	Normal

(*Cont'd...*)

Table 6. *Continued*

Variable	*p*-value	Normality
Q5.Regu	0.000	Not normal
Q5.Stk	0.000	Not normal
Q5.Sstn	0.000	Not normal
Q5.Risk	0.006	Not normal
Q5.Fin	0.000	Not normal
Q5.Ind	0.006	Not normal

Figure 3. Pearson correlation heatmap of numeric Environmental, Social, and Governance variables for internal stakeholders

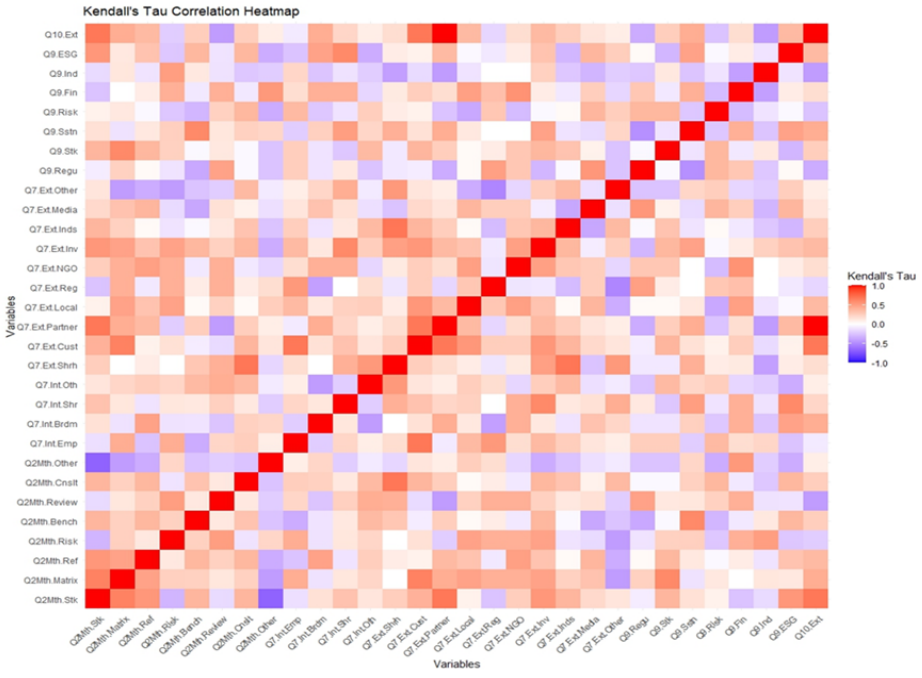

Figure 4. Kendall's Tau correlation heatmap among nominal variables for internal stakeholders

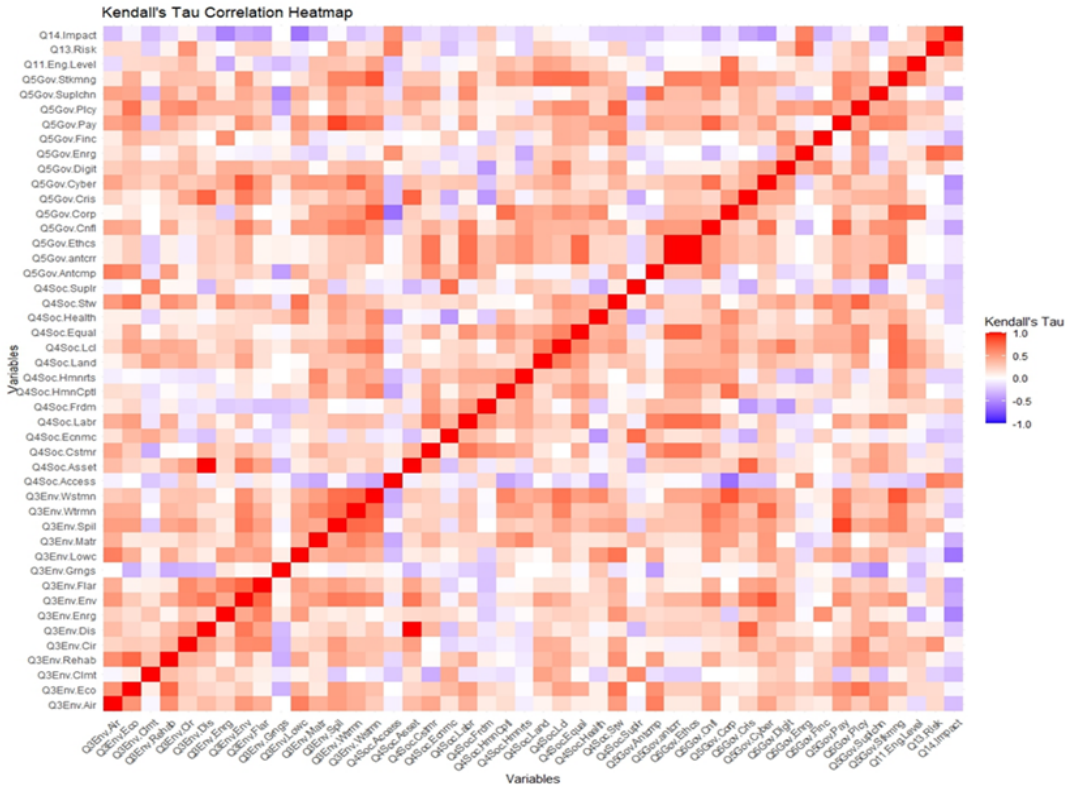

Figure 5. Kendall's Tau correlation heatmap among ordinal variables for internal stakeholders

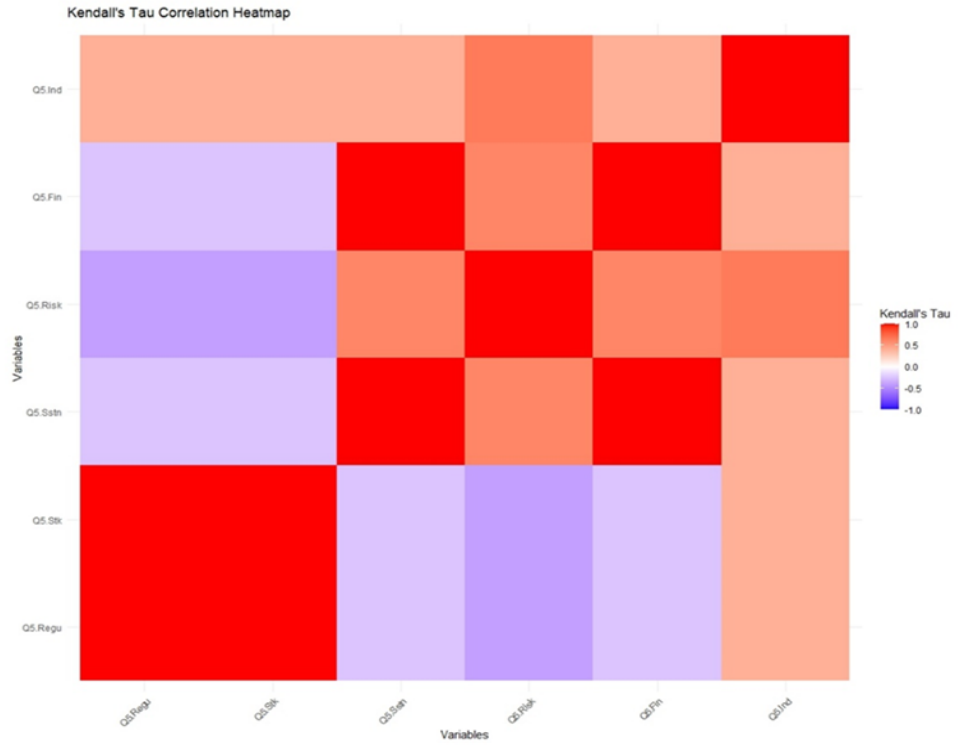

Figure 6. Kendall's Tau correlation heatmap among nominal variables for external stakeholders

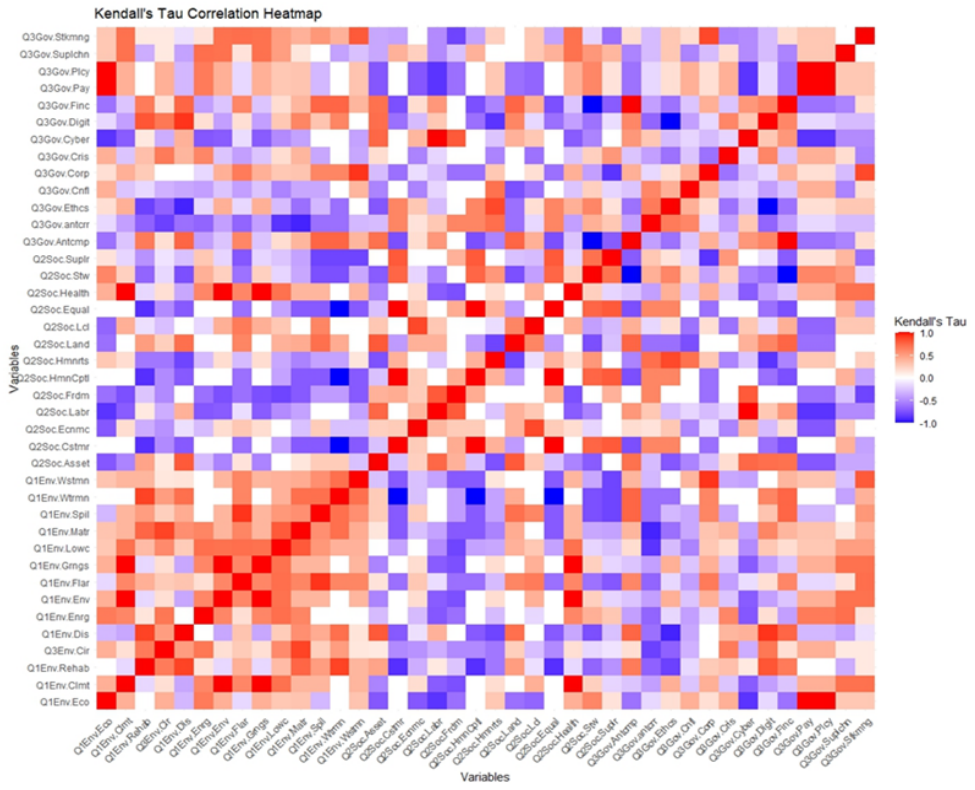

Figure 7. Kendall's Tau correlation heatmap among ordinal variables for external stakeholders

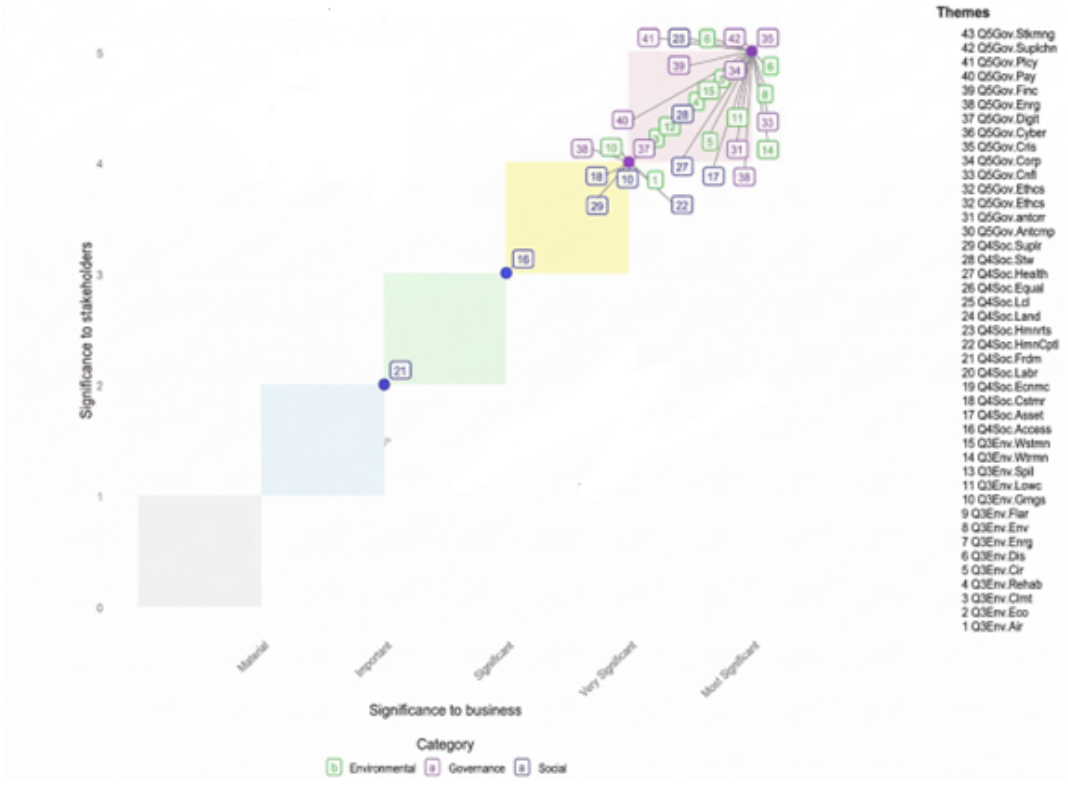

Figure 8. Materiality matrix for the upstream sector

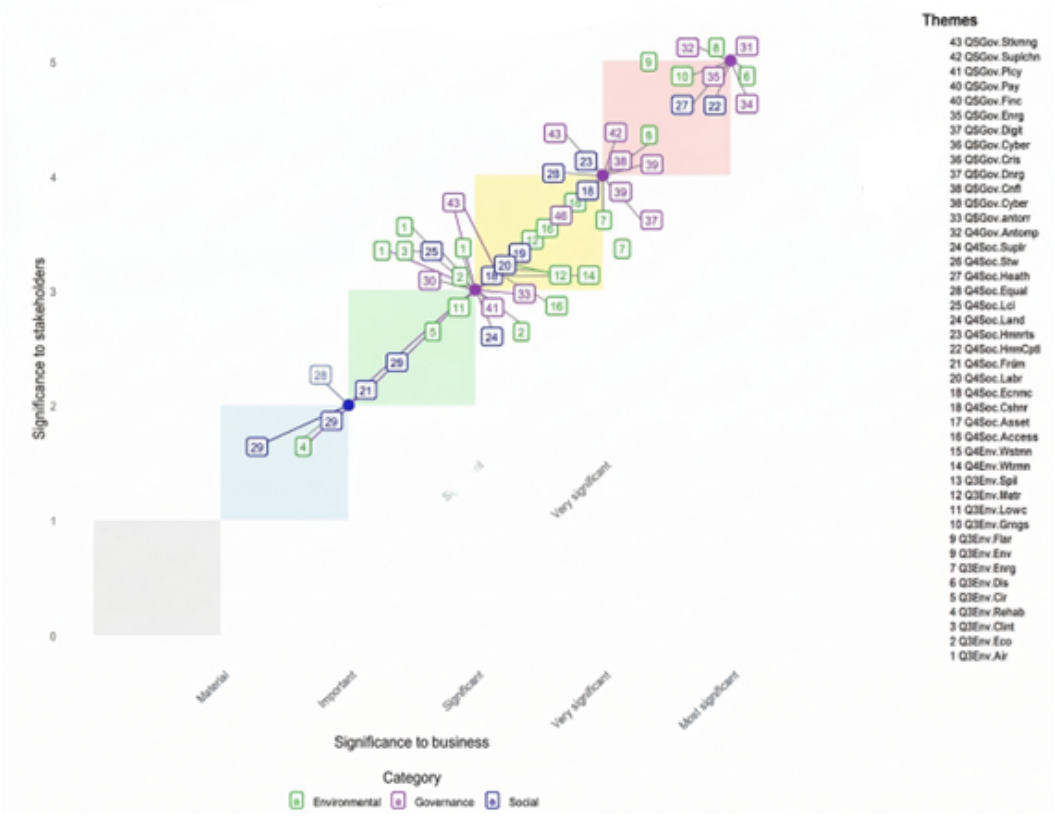

Figure 9. Materiality matrix for the midstream sector

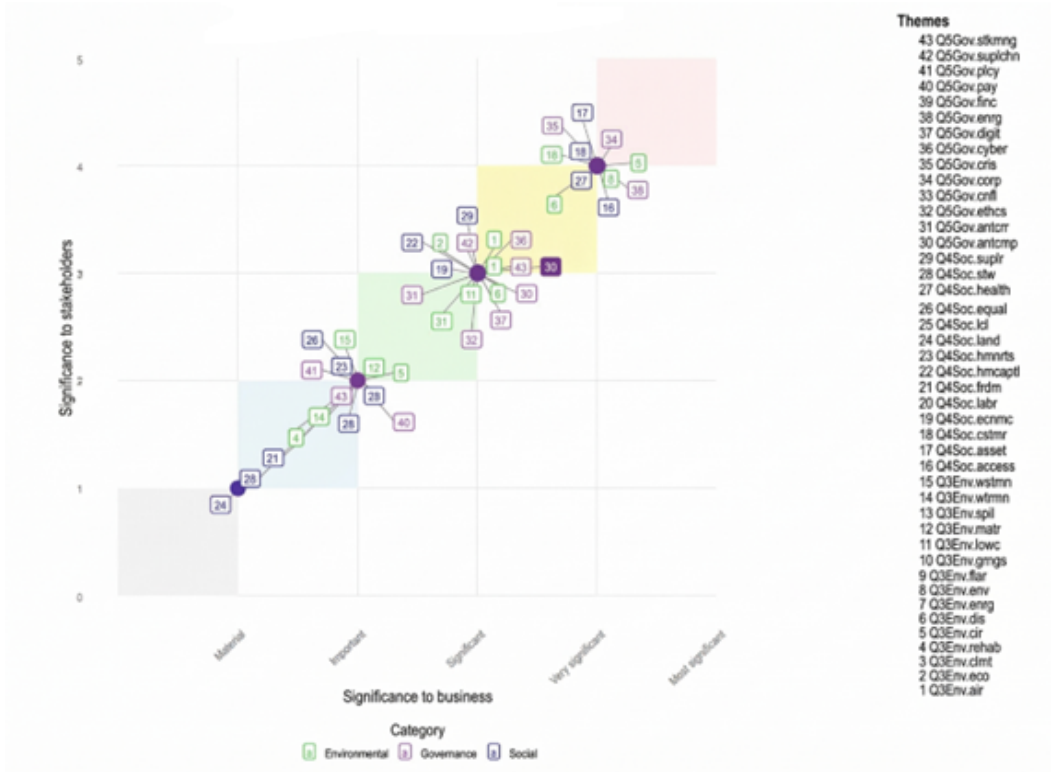

Figure 10. Materiality matrix for the downstream sector

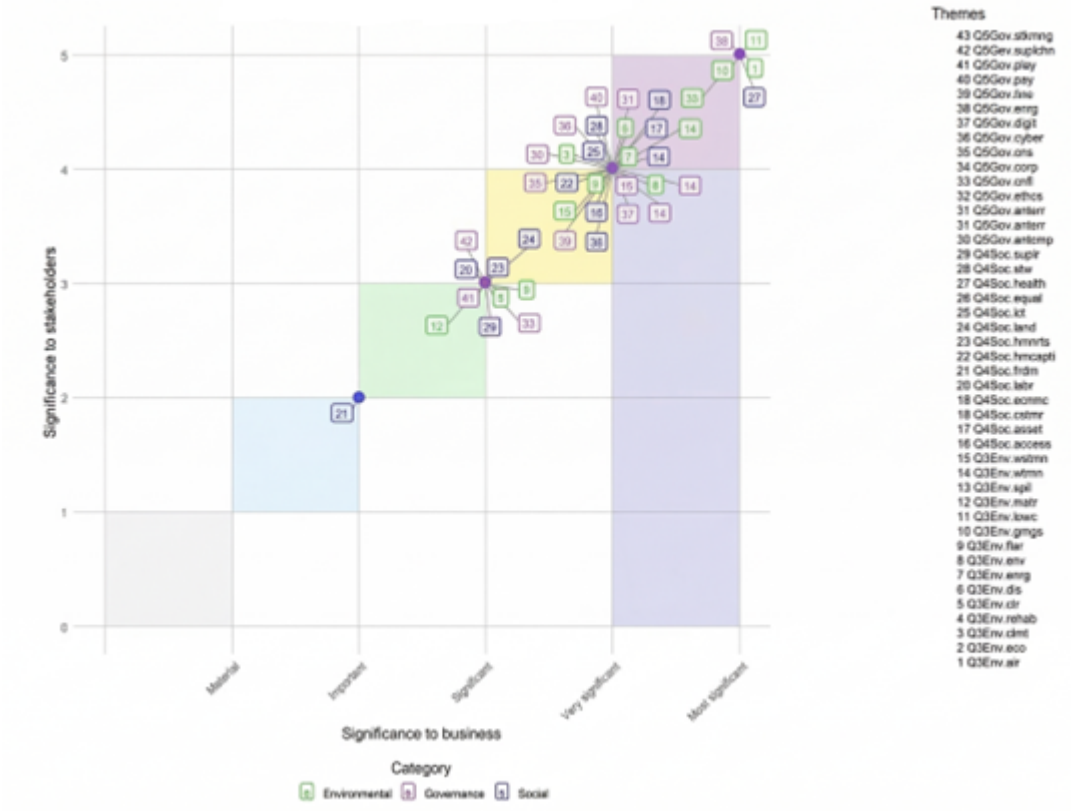

Figure 11. Materiality matrix for the integrated sector

Materiality matrices (Figures 8–11) prioritized ESG factors across sectors by plotting business and stakeholder significance, calculated as the average of 1–5 Likert-scale responses from internal (Q3–Q5) and external (Q1Env–Q3Gov) surveys. For internal stakeholders, upstream matrices emphasized GHG emissions (Q3Env.Grngs), water management (Q3Env.Wtrmn), and spill management (Q3Env.Spil), alongside health and safety (Q4Soc.Health) and regulatory compliance (Q5Gov.Corp). Midstream prioritized pipeline safety (Q4Soc.Asset), GHG emissions (Q3Env.Grngs), and stakeholder engagement (Q5Gov. Stkmng). Downstream focused on energy efficiency (Q3Env.Enrg), air pollution (Q3Env.Air), consumer safety (Q4Soc.Cstmr), and anti-corruption (Q5Gov.Antcrr). Integrated sectors highlighted GHG emissions (Q3Env. Grngs), climate policies (Q3Env.Clmt), and corporate governance (Q5Gov.Corp). External stakeholder ratings (e.g., Q1Env.Air, mean = 5.0; Q2Soc.Access, mean = 5.0) consistently elevated air emissions and access to energy across matrices, ensuring alignment with regulatory and societal expectations.

4.5. Sub-sectoral comparisons

Kruskal–Wallis tests revealed significant differences ($p \leq 0.05$) in internal stakeholder ESG rankings across upstream, midstream, downstream, and integrated sectors, reflecting distinct subsector priorities. For environmental factors, GHG emissions (Q3Env.Grngs, $\chi^2 = 7.55$, $p = 0.014$) varied, with Dunn's tests showing upstream prioritizing higher than midstream ($p = 0.021$) and integrated sectors ($p = 0.016$), likely due to drilling intensity (Figure 8). Water management (Q3Env.Wtrmn, $\chi^2 = 8.76$, $p = 0.032$) differed, likely reflecting upstream extraction requirements, and waste reduction (Q3Env.Wstmn, $\chi^2 = 9.55$, $p = 0.011$) showed downstream exceeding midstream ($p = 0.007$), reflecting consumer-facing pressures (Figure 10).

For social factors, product stewardship (Q4Soc.Stw, $\chi^2 = 9.63$, p = 0.02194) varied, with downstream emphasizing consumer safety (Figure 10), while midstream focused on operational impacts (Figure 9). Governance factors, such as corporate governance (Q5Gov.Corp), showed no statistically significant differences ($p > 0.05$), although a trend emerged between midstream and downstream ($p = 0.009$), with midstream prioritizing operational transparency (Figure 9) and downstream focusing on ethical practices (Figure 10). These findings underscore the importance of subsector-specific ESG strategies: upstream targeting emissions, downstream enhancing waste and

social responsibility, and midstream strengthening governance to address operational risks.

4.6. Standards alignment

Cross-tabulation (Tables 7 and 8) assessed alignment of ESG factors with relevant standards for internal and external stakeholders. Internal stakeholders showed strong alignment for GHG emissions (Q3Env.Grngs), with eight out of 12 responses aligning with sustainability drivers (Q9.Sstn), and governance factors such as anti-corruption (Q5Gov.Antcrr), with seven out of 12 responses aligning with ESG frameworks (Q9.ESG).

Weaker alignment was observed for biodiversity (Q3Env.Eco), with only 4 out of 12 responses aligning with industry drivers (Q9.Ind), and supply chain sustainability (Q4Soc.Suplr), with 3 out of 12 responses for financial drivers (Q9.Fin), 8 out of 12 for sustainability (Q9.Sstn), and 7 out of 12 for risk (Q9.Risk). External stakeholders aligned air emissions (Q1Env.Air) and climate adaptation (Q1Env.Clmt) with regulatory (Q5.Regu) and sustainability (Q5.Sstn) drivers, each with four out of five responses, but showed gaps in flaring (Q1Env.Flar), with four out of five responses, and land rights (Q2Soc.Land), also with four out of five responses.

Both groups showed limited alignment with SDG 5 (gender equality, linked to Q4Soc.Equal and Q2Soc.Equal) and SDG 14 (life below water, linked to Q3Env.Eco and Q1Env.Eco), as responses for these factors were not strongly associated with the corresponding SDG-focused drivers. Heatmaps (Figures 12 and 13) visualized alignment strength, and a correlation matrix (Table 9) showed a weak negative correlation between ESG standard references and stakeholder engagement (Q2Mth.Ref vs. Q11.Eng.Level, $\tau = -0.18$), suggesting that standards may not fully drive governance practices.

Following the weak negative correlation ($\tau = -0.18$) observed between ESG standard references and governance engagement in Table 9, a detailed subsector-specific analysis of materiality was conducted to identify key ESG priorities. The materiality matrices (Figure 8–11) map the significance of ESG factors across upstream, midstream, downstream, and integrated sectors, revealing distinct priorities shaped by operational and stakeholder contexts. To provide a concise summary of these findings, Table 10–13 list the top material topics for each sector, categorized under the ESG dimensions, facilitating a clear comparison of subsector-specific ESG priorities. These tables complement the visual representation in the matrices, offering a structured overview for strategic decision-making in the Indian natural gas sector.

5. Discussion

The ESG materiality assessment of India's natural gas sector reveals distinct priorities across upstream, midstream, downstream, and integrated sectors, informing subsector-specific strategies aligned with global (e.g., GRI, SASB, IPIECA) and Indian (e.g., BRSR) standards. In the Indian oil and gas sector, ESG metrics such as carbon emission reduction and energy efficiency reflect consistent sustainability efforts, with Bharat Petroleum Corporation Limited leading among Indian companies, although gaps persist in workforce diversity and community investment.[30,31]

Upstream operations prioritize GHG emissions (Q3Env.Grngs), water management (Q3Env.Wtrmn), spill management (Q3Env.Spil), health and safety (Q4Soc.Health), and regulatory compliance (Q5Gov.Corp), reflecting the carbon-intensive nature of drilling (Figure 8). Midstream focuses on pipeline safety (Q4Soc.Asset), GHG emissions (Q3Env.Grngs), and stakeholder engagement (Q5Gov.Stkmng), addressing operational risks such as pipeline leaks (Figure 9). Downstream emphasizes energy efficiency (Q3Env.Enrg), air pollution (Q3Env.Air), consumer safety (Q4Soc.Cstmr), and anti-corruption (Q5Gov.Antcrr), driven by consumer and regulatory pressures (Figure 10). ESG policy transparency demonstrates minimal variability, reflecting a generally high standard across the sector, although Indian firms lag in renewable energy adoption compared to global counterparts.[17,32]

Integrated sectors balance GHG emissions (Q3Env.Grngs), climate policies (Q3Env.Clmt), and corporate governance (Q5Gov.Corp), reflecting their broad ESG scope (Figure 11). Sectoral comparisons confirm these differences, with upstream ranking GHG emissions higher than midstream and integrated sectors ($\chi^2 = 7.55$, $p = 0.014$), and downstream prioritizing waste reduction over midstream ($\chi^2 = 9.55$, $p = 0.011$), highlighting the need for tailored ESG approaches. These subsectoral differences should be interpreted cautiously, as small and uneven subgroup sizes may reduce statistical power and lead to inflated or unstable effect estimates.

Standards alignment shows internal stakeholders strongly align GHG emissions (8/12 responses, Q9.Sstn) and anti-corruption (7/12 responses, Q9.ESG) with frameworks, but biodiversity (4/12 responses, Q9.Ind) and supply chain sustainability (3/12 responses, Q9.Fin) are weaker. The BRSR framework lacks several environmental

Table 7. Cross-tabulation of internal stakeholder responses with Environmental, Social, and Governance standards alignment

Category	Q9.Regu	Q9.Stk	Q9.Sstn	Q9.Risk	Q9.Fin	Q9.Ind	Q9.ESG	Q9.Other
Q3Env.Air	5	5	8	7	3	4	7	0
Q3Env.Eco...20	5	5	8	7	3	4	7	0
Q3Env.Clmt	5	5	8	7	3	4	7	0
Q3Env.Rehab	5	5	8	7	3	4	7	0
Q3Env.Eco...23	5	5	8	7	3	4	7	0
Q3Env.Dis	5	5	8	7	3	4	7	0
Q3Env.Enrg	5	5	8	7	3	4	7	0
Q3Env.Env	5	5	8	7	3	4	7	0
Q3Env.Flar	5	5	8	7	3	4	7	0
Q3Env.Grngs	5	5	8	7	3	4	7	0
Q3Env.Lowc	5	5	8	7	3	4	7	0
Q3Env.Matr	5	5	8	7	3	4	7	0
Q3Env.Spil	5	5	8	7	3	4	7	0
Q3Env.Wtrmn	5	5	8	7	3	4	7	0
Q3Env.Wstmn	5	5	8	7	3	4	7	0
Q4Soc.Access	5	5	8	7	3	4	7	0
Q4Soc.Asset	5	5	8	7	3	4	7	0
Q4Soc.Cstmr	5	5	8	7	3	4	7	0
Q4Soc.Ecnmc	5	5	8	7	3	4	7	0
Q4Soc.Labr	5	5	8	7	3	4	7	0
Q4Soc.Frdm	5	5	8	7	3	4	7	0
Q4Soc.HmnCptl	5	5	8	7	3	4	7	0
Q4Soc.Hmnrts	5	5	8	7	3	4	7	0
Q4Soc.Land	5	5	8	7	3	4	7	0
Q4Soc.Lcl	5	5	8	7	3	4	7	0
Q4Soc.Equal	5	5	8	7	3	4	7	0
Q4Soc.Health	5	5	8	7	3	4	7	0
Q4Soc.Stw	5	5	8	7	3	4	7	0
Q4Soc.Suplr	5	5	8	7	3	4	7	0
Q5Gov.Antcmp	4	5	7	7	2	4	6	0
Q5Gov.antcrr	5	5	8	7	3	4	7	0
Q5Gov.Ethcs	5	5	8	7	3	4	7	0
Q5Gov.Cnfl	5	5	8	7	3	4	7	0
Q5Gov.Corp	5	5	8	7	3	4	7	0
Q5Gov.Cris	5	5	8	7	3	4	7	0
Q5Gov.Cyber	5	5	8	7	3	4	7	0
Q5Gov.Digit	5	5	8	7	3	4	7	0
Q5Gov.Enrg	5	5	8	7	3	4	7	0
Q5Gov.Finc	5	5	8	7	3	4	7	0
Q5Gov.Pay	5	5	8	7	3	4	7	0

(*Cont'd...*)

Table 7. *Continued*

Category	Q9.Regu	Q9.Stk	Q9.Sstn	Q9.Risk	Q9.Fin	Q9.Ind	Q9.ESG	Q9.Other
Q5Gov.Plcy	5	5	8	7	3	4	7	0
Q5Gov.Suplchn	5	5	8	7	3	4	7	0
Q5Gov.Stkmng	5	5	8	7	3	4	7	0

Table 8. Cross-tabulation of external stakeholder responses with Environmental, Social, and Governance standards alignment

Category	Q5.Regu	Q5.Stk	Q5.Sstn	Q5.Risk	Q5.Fin	Q5.Ind	Q5.ESG	Q5.Other
Q1Env.Air	4	4	4	3	4	2	5	0
Q1Env.Eco	4	4	4	3	4	2	5	0
Q1Env.Clmt	4	4	4	3	4	2	5	0
Q1Env.Rehab	4	4	4	3	4	2	5	0
Q1Env.Cir	4	4	4	3	4	2	5	0
Q1Env.Dis	4	4	4	3	4	2	5	0
Q1Env.Enrg	4	4	4	3	4	2	5	0
Q1Env.Env	4	4	4	3	4	2	5	0
Q1Env.Flar	4	4	4	3	4	2	5	0
Q1Env.Grngs	4	4	4	3	4	2	5	0
Q1Env.Lowc	4	4	4	3	4	2	5	0
Q1Env.Matr	4	4	4	3	4	2	5	0
Q1Env.Spil	4	4	4	3	4	2	5	0
Q1Env.Wtrmn	4	4	4	3	4	2	5	0
Q1Env.Wstmn	4	4	4	3	4	2	5	0
Q2Soc.Access	4	4	4	3	4	2	5	0
Q2Soc.Asset	4	4	4	3	4	2	5	0
Q2Soc.Cstmr	4	4	4	3	4	2	5	0
Q2Soc.Ecnmc	4	4	4	3	4	2	5	0
Q2Soc.Labr	4	4	4	3	4	2	5	0
Q2Soc.Frdm	4	4	4	3	4	2	5	0
Q2Soc.HmnCptl	4	4	4	3	4	2	5	0
Q2Soc.Hmnrts	4	4	4	3	4	2	5	0
Q2Soc.Land	4	4	4	3	4	2	5	0
Q2Soc.Lcl	4	4	4	3	4	2	5	0
Q2Soc.Equal	4	4	4	3	4	2	5	0
Q2Soc.Health	4	4	4	3	4	2	5	0
Q2Soc.Stw	4	4	4	3	4	2	5	0
Q2Soc.Suplr	4	4	4	3	4	2	5	0
Q3Gov.Antcmp	4	4	4	3	4	2	5	0
Q3Gov.antcrr	4	4	4	3	4	2	5	0
Q3Gov.Ethcs	4	4	4	3	4	2	5	0
Q3Gov.Cnfl	4	4	4	3	4	2	5	0
Q3Gov.Corp	4	4	4	3	4	2	5	0

(*Cont'd...*)

Table 8. *Continued*

Category	Q5.Regu	Q5.Stk	Q5.Sstn	Q5.Risk	Q5.Fin	Q5.Ind	Q5.ESG	Q5.Other
Q3Gov.Cris	4	4	4	3	4	2	5	0
Q3Gov.Cyber	4	4	4	3	4	2	5	0
Q3Gov.Digit	4	4	4	3	4	2	5	0
Q3Gov.Enrg	4	4	4	3	4	2	5	0
Q3Gov.Finc	4	4	4	3	4	2	5	0
Q3Gov.Pay	4	4	4	3	4	2	5	0
Q3Gov.Plcy	4	4	4	3	4	2	5	0
Q3Gov.Suplchn	4	4	4	3	4	2	5	0
Q3Gov.Stkmng	4	4	4	3	4	2	5	0

Table 9. Correlation matrix between Environmental, Social, and Governance standard references and stakeholder engagement levels

Variable	Q2Mth.Ref	Q11.Eng.Level
Q2Mth.Ref	1.0	−0.18
Q11.Eng.Level	−0.18	1.0

Figure 12. Heatmap of Environmental, Social, and Governance alignment for internal stakeholders

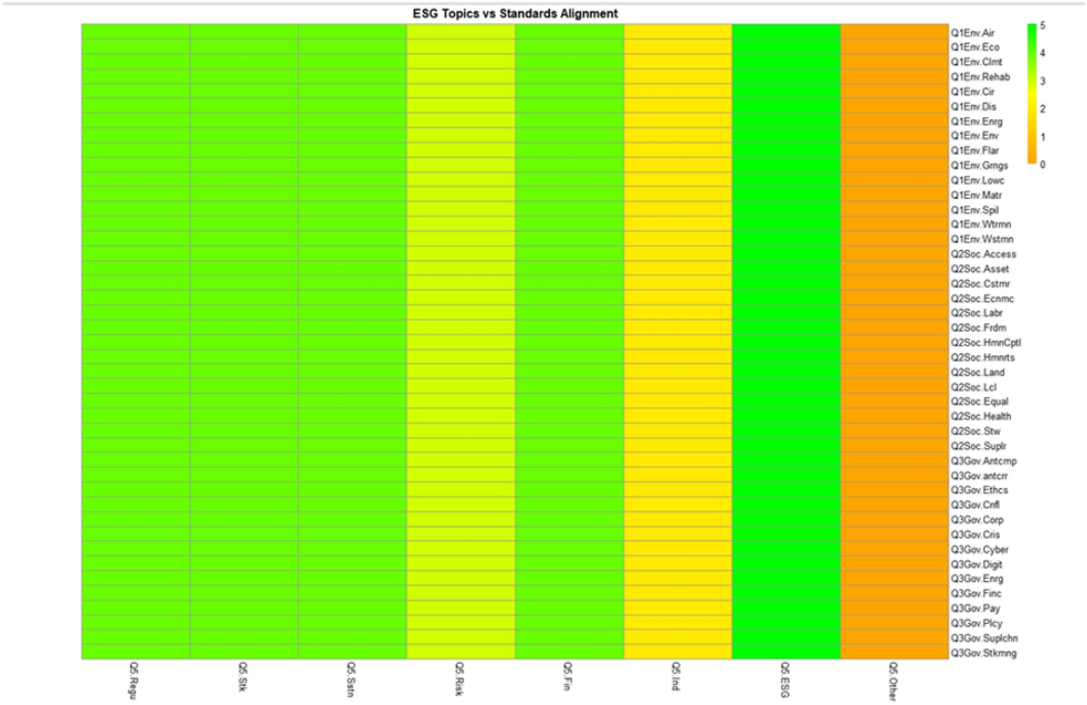

Figure 13. Heatmap of Environmental, Social, and Governance alignment for external stakeholders

Table 10. Materiality topics by the upstream sector

Environmental	Social	Governance
Greenhouse gas emissions	Health and safety	Ethical standards
Water management	Human rights	Stakeholder engagement
Climate risk	Impact on local communities	Board diversity and governance

Table 11. Materiality topics by the midstream sector

Environmental	Social	Governance
Greenhouse gas emissions	Health and safety	Stakeholder engagement
Energy efficiency	Working conditions	Crisis management
Flaring management	Community engagement	Pay for performance

Table 12. Materiality topics by the downstream sector

Environmental	Social	Governance
Energy efficiency	Consumer safety	Anti-corruption
Air pollution	Employee benefits	Cybersecurity
Renewable fuels	Diversity and inclusion	Business ethics

Table 13. Materiality topics by the integrated sector

Environmental	Social	Governance
Greenhouse gas emissions	Health and safety	Corporate governance
Climate risk	Human capital	Stakeholder engagement
Low-carbon technologies	Impact on local communities	Anti-corruption

parameters, including noise pollution and deforestation, creating challenges for industries in reporting, particularly in the energy sector.[18,33] External stakeholders align air emissions (Q1Env.Air) and climate adaptation (Q1Env. Clmt) with regulatory and sustainability drivers (4/5 responses each), with gaps in flaring (Q1Env.Flar) and land rights (Q2Soc.Land; also 4/5 responses). Limited alignment with SDG 5 (gender equality) and SDG 14 (life below water) across both groups indicates a persistent gap in addressing these global goals.

Heatmaps (Figures 12 and 13) highlight strong compliance for GHG emissions and air emissions, with gaps in flaring and SDG-related factors. A weak negative correlation ($\tau = -0.18$) between ESG standard references and engagement (Table 9) suggests that standards alone may not drive governance. The correlation matrix highlights relationships between ESG metrics and financial performance, offering insights into sustainability practices in the oil and gas sector.[34,35] While correlations such as emissions and low-carbon strategies ($\tau = 0.58–0.65$) were expected and may reflect ceiling effects in external ratings, they inform prioritization without implying causation.[36] Focus should be placed on decision-relevant gaps, such as biodiversity (16.7% alignment).[37] ESG disclosure scores do not appear to impact price discovery for most energy sector companies, with no long-term causality observed.[38]

6. Limitations

Though the purposive sampling strategy allowed only expert opinions to be considered in a selected group, it limited the number of respondents ($n = 17$) and provided less statistical power than could be achieved using a larger randomized sample or a mixed-source sampling approach. The Shapiro–Wilk test showed limited usefulness, as the data are ordinal, discrete, and bounded (1–5 scale) and therefore do not conform to a normal distribution; consequently, non-parametric analyses were used. Additionally, the self-reported survey and interview data collection methods pose a high risk of response bias. The rapid assessment, using a cross-sectional framework, did not allow for monitoring changes or progress over time in the research area. Geographic representativeness cannot be assumed when considering other countries or energy segments due to potential differences in regulatory structures (i.e., BRSR, renewables). Sensitivity tests indicated minor variability in effect sizes when imputation was excluded, highlighting the need for caution with small sample sizes. Specifically, the small sample size in some subsectors and stakeholder groups limits the strength and generalizability of subgroup analyses, underscoring the importance of larger, more balanced samples in future research. Future studies may include larger samples and incorporate mixed-methods analyses across social and environmental issues and energy sectors.

7. Conclusion and future prospects

This ESG materiality assessment for India's natural gas sector highlights key priorities across upstream, midstream, downstream, and integrated operations. Materiality matrices identify GHG emissions, water management, and stakeholder engagement as central concerns, with upstream focusing on emissions and downstream on energy efficiency, underscoring the need for tailored ESG strategies. Statistical analyses, including Kruskal–Wallis and Dunn's tests, confirm significant sectoral differences, supporting customized approaches. Key findings include significant sectoral differences in GHG emissions prioritization ($H = 7.55$, $p = 0.014$), with upstream showing greater concern than midstream and integrated segments, and downstream emphasizing waste reduction over midstream ($\chi^2 = 9.55$, $p = 0.011$). Alignment with global standards (e.g., GRI, SASB, IPIECA) and India's BRSR framework is strong for environmental factors, but gaps in biodiversity, supply chain sustainability, and SDG 5 (gender equality) and SDG 14 (life below water) highlight areas for improvement.

These findings provide valuable insights to guide sustainability efforts in the sector. Companies should focus on biodiversity conservation and sustainable supply chains to meet global benchmarks, while regulators can encourage compliance through incentive-based policies. Collaborative frameworks aligning internal governance with external stakeholder expectations are essential to address gaps. Future application of the proposed ESG materiality framework could be enhanced by increasing and better balancing sampling across different subsectors and stakeholder groups, which would enhance its statistical robustness and broader applicability. Additionally, adopting advanced analytics and real-time ESG monitoring will enhance responsiveness to emerging challenges. As India advances its energy transition, these steps will strengthen the sector's resilience, promoting sustainable growth and building stakeholder trust in a low-carbon future.

Acknowledgements

The authors gratefully acknowledge the following contributions: (i) the feedback from domain experts during the questionnaire validation process, which enhanced the clarity, relevance, and quality of the research instrument; (ii) the valuable insights provided by stakeholders during

the interviews, which informed and enriched the research findings; (iii) the support and participation of individuals who generously shared their time and perspectives; and (iv) the institutional support of Amity University, Noida, India, which facilitated access to research tools and resources.

Funding

None.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical approval and consent to participate

This study did not require formal ethical approval as it involved the voluntary participation of industry experts who provided insights based on their professional experience. Informed consent was obtained verbally and/or in writing from all participants prior to the interviews/surveys, and they were assured of confidentiality and the academic purpose of the study. Participants were free to withdraw at any stage, and the study adhered to established ethical guidelines for the research.

Consent for publication

All participants provided informed consent for the use and publication of their responses in this paper. Participants were informed that their data would be used for academic and research purposes, including publication in a peer-reviewed journal. No personal identifying information, images, or individual-level data are disclosed and all responses are reported in aggregate form, ensuring participant confidentiality throughout.

Availability of data

The interview data supporting this study contain identifiable information and are not publicly available due to ethical and confidentiality restrictions. Anonymized excerpts may be shared upon reasonable request and ethics approval.

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Appendix

Table A1. Variable explanation for internal stakeholders

Variable	Explanation
Q3Env.Air	Air quality and emission standards within the gas industry
Q3Env.Eco	Biodiversity conservation efforts and ecological impact
Q3Env.Clmt	Climate resilience strategies and adaptation planning
Q3Env.Rehab	Processes for closure, rehabilitation, and decommissioning
Q3Env.Cir	Circular economy initiatives within gas operations
Q3Env.Dis	Disaster and emergency response management practices
Q4Soc.Asset	Ensuring asset integrity and incident response measures
Q3Env.Enrg	Energy efficiency and consumption management strategies
Q3Env.Env	Environmental compliance regulations and reporting
Q3Env.Flar	Management of flaring and venting within operations
Q3Env.Grngs	Greenhouse gas emissions control measures
Q3Env.Lowc	Adoption of low-carbon and clean energy technologies
Q3Env.Matr	Material procurement and sustainability considerations
Q3Env.Spil	Pollution control and spill management strategies
Q3Env.Wtrmn	Water resource management and conservation
Q3Env.Wstmn	Waste reduction and recycling strategies
Q4Soc.Access	Energy affordability and access for consumers
Q4Soc.Cstmr	Customer relations and service quality management
Q4Soc.Ecnmc	Economic impact and contribution of the gas industry
Q4Soc.Labr	Addressing forced labor and modern slavery concerns
Q4Soc.Frdm	Freedom of association and collective bargaining rights
Q4Soc.HmnCptl	Workforce management and human capital policies
Q4Soc.Hmnrts	Protection of human and indigenous rights
Q4Soc.Land	Land acquisition and resource rights management
Q4Soc.Lcl	Community engagement and local development projects
Q4Soc.Equal	Equal opportunity, non-discrimination, and diversity
Q4Soc.Health	Occupational health and workforce safety policies
Q4Soc.Stw	Sustainable product stewardship and life-cycle management
Q4Soc.Suplr	Supplier social assessment and ethical sourcing
Q5Gov.Antcmp	Regulation of anti-competitive behaviors in the industry
Q5Gov.antcrr	Policies addressing anti-corruption and bribery risks
Q5Gov.Ethcs	Business ethics, integrity, and corporate transparency
Q5Gov.Cnfl	Conflict resolution and security management
Q5Gov.Corp	Corporate governance, compliance, and legal oversight
Q5Gov.Cris	Crisis management and preparedness planning
Q5Gov.Cyber	Cybersecurity policies and data protection measures
Q5Gov.Digit	Adoption of digital transformation technologies
Q5Gov.Enrg	Energy security policies and infrastructure development

(*Cont'd...*)

Table A1. *Continued*

Variable	Explanation
Q5Gov.Finc	Financial sustainability and long-term resilience planning
Q5Gov.Pay	Financial transactions and payments to government bodies
Q5Gov.Plcy	Public policy engagement and advocacy efforts
Q5Gov.Suplchn	Ethical and sustainable supply chain management
Q5Gov.Stkmng	Stakeholder engagement strategies and communication
Q11.Eng.Level	Involvement of the governing body in ESG decision-making
Q13.Risk	Integration of ESG assessments with enterprise risk management
Q14.Impact	Effectiveness of ESG assessments in identifying key risks
ExpGas	Work experience in the gas industry
ExpSus	Work experience in sustainability-related roles

Abbreviation: ESG: Environmental, Social, and Governance.

Table A2. Variable explanation for external stakeholders

Variable	Explanation
Name	Respondent's name
Type	Type of respondent (e.g., regulator, investor, non-governmental organization)
Dsgn	Designation of the respondent
Dpt	Department of the respondent
Org	Organization the respondent belongs to
Relationship	Relationship with the gas industry (e.g., customer, supplier)
Consent	Consent provided for participation
Q1Env.Air	Perception of air emissions impact on communities
Q1Env.Eco	Biodiversity conservation and external ecological concerns
Q1Env.Clmt	Climate adaptation policies and their industry implications
Q1Env.Rehab	Restoration and rehabilitation efforts post-operations
Q1Env.Cir	Circular economy adoption in industrial supply chains
Q1Env.Dis	Disaster response capabilities from an external perspective
Q1Env.Enrg	Public and regulatory concerns on energy management
Q1Env.Env	Compliance expectations from environmental organizations
Q1Env.Flar	Venting and flaring impact on surrounding communities
Q1Env.Grngs	GHG reduction expectations from external bodies
Q1Env.Lowc	Clean energy transitions and external stakeholder views
Q1Env.Matr	Material usage and impact on external sustainability goals
Q1Env.Spil	Pollution and environmental spill response efficiency
Q1Env.Wtrmn	Water resource usage from a regulatory perspective
Q1Env.Wstmn	Waste disposal and its compliance with environmental laws
Q2Soc.Access	Access to affordable energy for marginalized communities
Q2Soc.Asset	External evaluation of asset integrity and risk management
Q2Soc.Cstmr	Consumer feedback on service quality and reliability

(*Cont'd...*)

Table A2. *Continued*

Variable	Explanation
Q2Soc.Ecnmc	Economic impacts on broader society and employment
Q2Soc.Labr	Forced labor concerns from a regulatory viewpoint
Q2Soc.Frdm	Freedom of association rights assessed externally
Q2Soc.HmnCptl	Workforce policies evaluated by labor organizations
Q2Soc.Hmnrts	Human rights violations and social impact concerns
Q2Soc.Land	Land rights issues from the perspective of affected communities
Q2Soc.Lcl	Community engagement effectiveness and feedback
Q2Soc.Equal	Diversity and inclusion efforts assessed by external stakeholders
Q2Soc.Health	Health and safety concerns from external agencies
Q2Soc.Stw	Sustainability of gas products from a consumer standpoint
Q2Soc.Suplr	Supplier assessments from third-party auditors
Q3Gov.Antcmp	Fair competition practices from an external regulatory lens
Q3Gov.antcrr	Anti-corruption measures viewed from transparency agencies
Q3Gov.Ethcs	Corporate ethics evaluated by consumer organizations
Q3Gov.Cnfl	Security risks impacting external stakeholders
Q3Gov.Corp	Governance effectiveness assessed externally
Q3Gov.Cris	Crisis management transparency to external observers
Q3Gov.Cyber	Data privacy concerns raised by third parties
Q3Gov.Digit	Digitalization efforts and cybersecurity for external users
Q3Gov.Enrg	Energy security impact on external businesses
Q3Gov.Finc	Financial performance and investor confidence
Q3Gov.Pay	Government payments viewed from tax and policy groups
Q3Gov.Plcy	Public policy advocacy from a civil society perspective