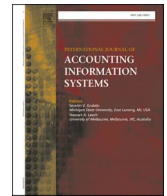




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A new way to analyze ESG reports: A theme based model supported by AI[☆]

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ABSTRACT

Sustainability reports are often long, complex, and poorly standardized, making it difficult to extract comparable and meaningful information across companies. Despite increasing regulatory pressure, including the EU's Corporate Sustainability Reporting Directive (CSRD) and European Sustainability Reporting Standards (ESRS), the quality, clarity, and usefulness of ESG disclosures remain questionable. Neither manual nor automated analyses have fully resolved these challenges.

This study introduces a transparent and replicable methodological framework for organizing heterogeneous ESG reports into structured thematic summaries. Rather than applying predefined categories, the approach begins with the reports themselves: ESG disclosures are reviewed and similar passages grouped inductively into seven shared ESG themes. Theme-specific keywords and contextual filters are then derived to support AI-assisted retrieval across a larger dataset. The framework was applied to 393 sustainability reports from publicly listed EU companies.

The findings demonstrate that the inductively derived thematic structure can be applied consistently across large datasets while preserving interpretability. The framework produces structured summaries showing which ESG topics are addressed, how extensively, and at what level of specificity, providing a foundation that users can begin to interpret and compare in a manner of their choosing. Developing and validating formal comparison methods lies beyond the scope of this study and represents a direction for future research.

1. Introduction

The importance of sustainability reporting has increased significantly in recent years, driven by regulatory developments, investor expectations, and broader societal demands (Christensen et al., 2021; Kotsantonis and Serafeim, 2019; Haji et al., 2023). In the European Union, the Corporate Sustainability Reporting Directive (CSRD) and the associated European Sustainability Reporting Standards (ESRS) represent the most significant reform of corporate sustainability reporting in decades. The EU directive expands the previous reporting mandate from 2017 from approximately 11,700 to over 50,000 companies and requires comprehensive,

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standardized, digitally published, and machine-readable¹ sustainability reports (European Commission, 2023; EFRAG, 2023).

Despite these reforms and the corresponding increase in digitalized and machine-readable sustainability reports, the quality, clarity, comparability, and usefulness of environmental, social and governance (ESG) disclosures within these reports remain questionable (Lin et al., 2024; Aluchna et al., 2023). Lin et al. (2024) show that mandatory reporting can increase volume while reducing the clarity and usefulness of the content. Aluchna et al. (2023) note that while regulation can improve ESG performance, the quality and usability of sustainability reports still vary significantly. Sustainability reports are often long, complex, and poorly standardized (e. g., the same topic appears in different sections or is presented using varied language), which makes it difficult for readers to extract comparable and meaningful information across companies or to determine what has been reported and to what extent (Kotsantonis and Serafeim, 2019; Christensen et al., 2021; Hasan, 2022).

To date, the use of either manual or automated analyses of sustainability reports has failed to yield desired improvements in information usefulness. Manual analyses are labor intensive and time consuming, particularly when applied to large datasets (Hasan, 2022). Automated analyses have limited effectiveness unless the content is preprocessed and systematically structured. Traditional content analysis methods also do not scale well to large datasets, and commercial ESG rating systems offer limited transparency into text-based sources (Lin et al., 2024; IOSCO,² 2021; Berg et al., 2022). Therefore, analyzing and interpreting ESG reports requires not only subject matter expertise but also a methodological framework that can organize and highlight relevant content in a coherent way (Kotsantonis and Serafeim, 2019).

This study addresses these challenges by introducing a transparent, repeatable, and accessible framework for identifying and assessing ESG-related content in sustainability reports. It adopts a Design Science Research (DSR) approach and focuses on the design and demonstration phases of the DSR process (Peffer et al., 2008). The design begins with manual analysis of the reports themselves: rather than using predefined categories, ESG disclosures are reviewed to identify what companies report and similar passages are grouped into shared ESG themes (i.e., derived from the data) through inductive coding. The analytical approach is then applied to a larger dataset using AI. This two-stage design, combining manual analysis with AI-assisted scaling, supports both conceptual consistency and practical applicability of the method.

The purpose of this study is to introduce a methodological approach that systematically structures heterogeneous sustainability reports. By organizing the content in these reports into summarized topics and themes, users can begin to make sense of the disclosed information; for example, by identifying patterns or comparing across company reports. The study does not attempt to define a universal or exhaustive set of ESG themes applicable to all companies. Yet, by coming up with a thematic structure that organizes ESG disclosures into profiles, the study can show which topics are addressed, how extensively they are discussed, and at what level of specificity across firms.

The contribution of this research lies in providing a transparent and replicable model for structuring ESG reporting data that can be used with AI. Earlier research has examined ESG ratings, symbolic language, or report structures, but it has not fully addressed scalable, theme-based content analysis approaches that can be examined against CSRD and ESRS requirements (Nicolas et al., 2023; Bashir et al., 2024; Dragomir et al., 2024). By combining manual interpretation with AI-assisted scalability, the proposed model addresses the shortcomings of prior research and offers an alternative to traditional content analysis approaches that are difficult to scale or commercial ESG tools that often have opaque underlying methodologies. To be clear, the method in this study does not directly rank or score companies. Instead, it produces a structured summary of each company's ESG reporting content that users can begin to interpret in a manner of their choosing.

The remainder of this paper is as follows. Section 2 provides the theoretical background, followed by the methodology and data in Section 3. Section 4 presents the results. Section 5 concludes with the contribution of the paper, limitations, and suggestions for further research.

2. Theoretical background

2.1. Development and challenges of sustainability reporting

Sustainability reporting has evolved from voluntary disclosure into a heavily regulated practice within the European Union. The Corporate Sustainability Reporting Directive (CSRD) and European Sustainability Reporting Standards (ESRS) now mandate comprehensive, standardized reporting for over 50,000 companies, defining principles of double materiality, information structure, and disclosure format (European Commission, 2022; Stefani and Gabor, 2025; EFRAG, 2022).

Despite this regulatory push, the quality and usefulness of ESG disclosures remain contested. Reports have grown longer but less precise, a phenomenon Lin et al. (2024) describes as “reporting inflation,” where volume increases while informational value diminishes. Much of this content reflects symbolic reporting: communication that is intentionally vague or selective, emphasizing sustainability rhetorically rather than through concrete actions, primarily to maintain organizational legitimacy (Deegan, 2002; Suchman, 1995; Gu et al., 2024).

Symbolic reporting carries real consequences. Many ESG reports contain extensive content-free filler text that fails to provide

¹ EFRAG (European Financial Reporting Advisory Group) is the body responsible for developing the European Sustainability Reporting Standards (ESRS) under the CSRD framework.

² IOSCO (International Organization of Securities Commissions) is the international body that sets global standards for securities regulation, including guidance on ESG ratings and data providers.

transparency or meaningful impact assessment (Dragomir et al., 2024), and when disclosed commitments contradict actual actions, companies face reputational sanctions in financial markets (Nicolas et al., 2023). In more extreme cases, symbolic disclosures develop into greenwashing, where companies actively misrepresent their sustainability performance, for example by claiming climate alignment while continuing to invest in fossil fuels (Deegan, 2002; Deegan, 2019). These challenges are compounded by inconsistencies in terminology and reporting scope, which further complicate comparative analysis across companies.

ESG reports typically combine numerical and narrative data whose relevance depends on context and terminology, a complexity that existing analytical approaches have struggled to address. Manual analysis offers interpretive depth but does not scale to large datasets (Lin et al., 2024). Commercial ESG rating systems such as Bloomberg, MSCI, and LSEG aim to standardize assessment but suffer from significant opacity: their weighting schemes, aggregation rules, and scoring algorithms are rarely disclosed (IOSCO, 2021; Berg et al., 2022). As a result, ESG ratings may reflect reporting practices rather than actual sustainability performance and often rely on self-reported data without independent assurance (Aluchna et al., 2023).

Recent literature has increasingly turned to NLP and AI-assisted methods to address these challenges, including word embeddings and regulation-specific models such as ESGReveal and ESG BERT (Lin et al., 2024; Gu et al., 2024). However, these approaches have not fully addressed the need for scalable, theme-based content analysis that systematically structures heterogeneous sustainability reports by organizing their content into summarized topics and themes.

2.2. Research approach and artifact design

This study follows the Design Science Research Methodology (DSRM) proposed by Peffers et al. (2008), which outlines a systematic process for developing and evaluating practical artifacts through problem identification, design, demonstration, and evaluation phases (Hevner et al., 2004). Research contributions within this framework are typically iterative, with artifacts refined progressively in empirical contexts. In this study, the artifact refers to the thematic ESG content identification model as a whole, comprising the inductively derived seven-theme structure, the associated keyword frameworks, and the contextual filters used to support AI-assisted retrieval.

Applying DSR in ESG-related contexts requires attention to both technical functionality and domain relevance (Geerts, 2011). In sustainability reporting, this is particularly important due to the complexity and variability of ESG disclosures, as well as the influence of regulatory frameworks. Prior research highlights that even within standardized reporting environments, substantial variation exists in reporting quality and practices (Dragomir et al., 2024), underscoring the need for structured and context-sensitive analytical approaches.

3. Methodology and data

This study developed a methodological framework for transforming heterogeneous sustainability reports into a shared thematic structure through a two-stage process: manual inductive coding followed by AI-assisted scaling.

In the manual phase, sustainability reports were read in parallel and relevant passages coded based on what companies actually reported regarding ESG-related actions, targets, governance practices, risks, and operational measures. Similar passages were grouped inductively, and through this process seven ESG themes were identified: Carbon Footprint & Energy Efficiency Management, ESG Metrics & Monitoring, ESG Data Reliability & Assurance, Climate Change Risk Reporting, Circular Economy & Resource Efficiency, ESG in Business Governance, and Stakeholder Impacts. The associated keyword structures for each theme are provided in the Appendix.

Only after these themes were established were theme-specific keywords and contextual filters derived to support AI-assisted retrieval of thematically related content across reports. Each theme was linked to a carefully constructed keyword group representing essential concepts and expressions, developed through iterative manual review. This allowed the system to identify and organize how different companies addressed the same ESG-related themes.

The analytical process followed the principles of qualitative content analysis, beginning with a systematic review of the data to identify recurring topics, linguistic emphases, and phenomena (Braun and Clarke, 2006). The initial coding phase identified key content from which the themes were constructed, capturing not only the structure of the data but also the relationships between the phenomena (Mayring, 2014).

3.1. Data processing

All analyzed sustainability reports were in English, which eliminated the need for translation and multilingual processing stages. The dataset included both standalone sustainability reports and ESG sections embedded in corporate annual reports. Reporting styles and lengths varied significantly, with some reports being concise summaries and others spanning several hundred pages.

For the manual phase, all 52 companies listed on the Nasdaq Nordic³ Large Cap index were included, excluding financial sector firms because their reporting practices differ significantly from those of other industry sectors. This resulted in 104 sustainability and annual reports covering the reporting years 2023 and 2024. The choice of the Nordic Large Cap market was deliberate: these

³ Nasdaq Nordic Large Cap is a segment of the Nasdaq Nordic exchange comprising companies with large market capitalization listed in Nordic countries.

companies are among the largest and most visible in the region, subject to intense investor scrutiny and early adopters of CSRD/ESRS requirements. Focusing on a relatively homogeneous group of large EU-listed firms also ensured that the reports were comparable in scope and structure, which is critical when developing and testing a methodological framework. The aim was not to build a globally generalizable ESG taxonomy but to demonstrate how a consistent thematic framework can be constructed and applied within a well-defined group of companies.

Once the thematic framework had been developed, the themes were examined against CSRD and ESRS definitions to identify which ESG reporting domain each theme represented and to verify that the framework covered the relevant reporting topics (Krippendorff, 2013). The framework's scalability was then tested using AI with a larger dataset consisting of 289 companies from the STOXX Europe 600 index (excluding financial sector firms). Reports for the year 2024 were selected because they represent the first mandatory ESG disclosures under the CSRD. AI was used to test whether the manually derived thematic framework could be scaled efficiently to a broader and more diverse EU-wide dataset, not to generate new themes or analytical categories.

To ensure thematic relevance, content was reviewed using concrete strategic indicators to distinguish substantive disclosures from symbolic or generic language, which has been a well-documented challenge in ESG reporting (Luccioni et al., 2020; Lin et al., 2024). These indicators were developed during the iterative manual coding process and include measurable targets (e.g., specific reduction percentages or numerical goals), timelines or deadlines (e.g., target years for achieving stated objectives), and verifiable actions (e.g., implemented measures rather than general intentions). A passage was considered substantive only when it contained at least one of these elements, ensuring that vague or rhetorical statements were excluded from the thematic analysis.

3.2. Manual content analysis with NVivo

The manual phase of the study focused on identifying what companies actually address in their sustainability reporting, rather than searching for predefined ESG categories. Sustainability reports were read in full using NVivo software, with attention directed to passages where companies described concrete actions, targets, risks, policies, or decisions related to environmental, social, or governance issues. In other words, the analysis focused on substantive responses provided by companies, not on generic statements or rhetorical commitments.

During this phase, reports were reviewed in parallel in small batches of four documents at a time. Relevant passages were manually coded at the sentence or paragraph level whenever a company addressed a specific sustainability-related issue in a concrete manner. Coding decisions were based on contextual interpretation: a passage was included only if it described identifiable actions, objectives, risks, timelines, investments, or governance mechanisms. This ensured that the analysis captured meaningful content rather than symbolic or boilerplate language.

As relevant passages accumulated, similarities between coded passages became visible. Passages addressing similar issues were grouped together inductively. These groups gradually formed shared thematic structures, which later became the seven ESG themes. Importantly, the themes were not defined in advance. They emerged as the outcome of repeated comparison across reports, reflecting what companies consistently addressed in practice.

Only after these themes had been established were keywords derived. Keywords were extracted from the already coded passages and were selected based on their ability to reliably identify thematically relevant content. Keywords therefore functioned as a technical extension of the manual interpretation, not as an independent classification mechanism. This step enabled scalable identification of similar content while preserving the interpretive logic developed during manual coding.

Table 1 presents the double-materiality orientation framework used to guide manual content analysis. The framework was not applied as a predefined coding scheme or as a source of ESG themes. Instead, it served as an interpretive reference to delimit the analytical focus in line with CSRD and ESRS requirements. During manual coding, report passages were first identified inductively based on what companies addressed in their reporting. Only after content had been coded and grouped were the themes compared against the double-materiality framework to ensure that both impact materiality and financial materiality perspectives were appropriately covered. Thus, Table 1 functions as a regulatory alignment tool rather than a classificatory mechanism, ensuring relevance without determining analytical outcomes.

Table 1
Double-materiality orientation framework used to guide manual analysis.

Evaluated Factor	Environmental Materiality (Company's Impact on Environment and Society)	Financial Materiality (Impact of Sustainability Factors on Company)
Climate Change	Company's carbon footprint, emissions reduction efforts, energy efficiency	Regulatory changes (emissions trading, carbon taxes), investment risks, consumer attitudes
Biodiversity	Impact of raw material sourcing on ecosystems, biodiversity	Regulation, availability of raw materials, significance of sustainability to investors
Social Responsibility	Respect for labor conditions and human rights in the value chain	Reputation management, customer loyalty, stakeholder relations
Governance and Ethics	Company's transparency, openness, and ethical practices	Corruption risks, regulatory requirements, investor trust
Circular Economy and Resource Efficiency	Waste management, use of recycled materials	Potential savings, availability of resources, price fluctuations

The table has been created using the guidelines provided by EFRAG (2023).

The manual coding process was iterative. After an initial set of reports had been coded, the emerging keywords were used to identify additional potentially relevant passages, which were then manually reviewed and either confirmed or rejected based on context. This iterative process continued until no substantially new thematic content was identified, indicating conceptual saturation.

To assess the substantive significance of the identified passages, an impact scale was applied (Table 2). Passages scoring at level 1, indicating no meaningful mention or only generic references to sustainability, were excluded from the analysis. This filtering step helped distinguish genuine sustainability practices from symbolic, boilerplate, or greenwashing-type language, ensuring that the thematic framework was built on content with real strategic or operational significance. The objective was not to rank companies, but to ensure that only passages describing identifiable actions, concrete targets, or specific governance mechanisms were retained. After the initial theme construction, the keyword lists of each theme were further refined using the same logic, a term was accepted only if it appeared in a semantically meaningful and specific context rather than in generic or rhetorical statements. This approach goes beyond traditional keyword-based methods, which have been criticized for shallow interpretation and their inability to capture contextual meaning (Gu et al., 2024).

To evaluate coding consistency, a random sample of previously coded report passages was manually re-examined and compared with the original coding decisions. The same material was also used to evaluate whether the developed keyword sets consistently retrieved the manually identified passages. Any discrepancies were reviewed and resolved by refining the coding guidelines, particularly in areas where the boundaries of the themes overlapped. This phase ensured the repeatability of theme development and conceptual validity and created the methodological foundation for the transparent interpretation logic of the AI system in accordance with the DSR approach (Geerts, 2011; Peffers et al., 2008).

3.3. Use of artificial intelligence

The AI component used in this study was OpenAI's ChatGPT (ChatGPT, 2023, gpt-4-turbo), which was applied to interpret the content of ESG reports using predefined themes and their keywords developed during the manual analysis phase. In this study, AI was a supportive tool to accelerate data processing and test whether the manually derived thematic framework could be applied consistently across a much larger dataset. This design decision ensured that the framework retained methodological transparency and interpretability, which are essential for both academic and regulatory contexts. Once the thematic framework and associated keywords were established through manual analysis, AI enabled rapid identification of thematically relevant passages in additional reports without reintroducing subjective reinterpretation. Scalability refers to extending a validated qualitative method to larger datasets while preserving its original interpretive structure.

Instead of fine-tuning the model, the analysis used guided, rule-based prompts, which allow flexibility and transferability across different ESG applications. This design decision aligns with current literature, where sector-specific, rule-based AI applications are seen as a promising path toward explainable and context-sensitive analytical tools (Ranta et al., 2023). Each prompt followed a standardized structure applicable to all seven themes, emphasizing repeatability, transparency, and consistency. The prompts functioned as retrieval instructions that operationalized the manually derived thematic framework, directing the AI to search for, filter, and extract thematically relevant passages based on predefined keywords and contextual criteria, rather than to classify or interpret content independently. To illustrate, the following example shows the core prompt logic applied to Theme 3 (ESG Data Reliability & Assurance):

“Execute the analysis fully automatically, without interruptions. All responses must be based solely on the contents of the analyzed document. Do not paraphrase or summarize, return only exact quotes from the source text.

Step 1: Identify structural elements and prioritize sections containing ESG- or sustainability-related terms (e.g., sustainability, ESG, governance, materiality). If no such sections are identifiable, perform the keyword search across the entire document.

Step 2: Search for paragraphs containing the theme-specific keywords (listed in the Appendix). Include synonyms and recognized abbreviations.

Step 3: Filter hits according to the theme-specific filtering criteria (defined in the Appendix).

Step 4: Extract the full paragraph containing the keyword (up to 10 sentences). If the keyword appears in a list or table, extract the nearest explanatory paragraph. If no paragraph exists, use sentence-level extraction (two sentences before and after the keyword). Return at least 10 hits per theme.

Table 2
Impact scale.

Scale	Description	Rationale
1 No mention / Not important	The variable is not mentioned or only mentioned briefly.	No mention or only a general reference to sustainability.
2 Minor impact	The variable is mentioned but is not central to strategy or risk management.	Development goals mentioned, but no concrete figures.
3 Significant, but not critical	The variable has an impact but does not significantly affect business.	Goals and figures mentioned, but no investments or direct financial impacts.
4 Critical, affects business	The variable is directly linked to business development, risks, or strategy.	Risks included in financial reporting, investments in sustainability.
5 Strategic core / Major impact	The variable is crucial for business and drives decision-making.	ESG integrated into financial reporting, large investments, and regulation driven changes.

Output format: Company name, Theme title, Extracted quote.”

A key methodological advantage of this keyword-based approach relates to the verifiability of results. Because the keywords were derived directly from manually coded passages, the researcher could anticipate what content the AI should retrieve for each theme. This prior knowledge made it possible to evaluate whether the AI-assisted retrieval produced consistent and thematically appropriate results, without relying solely on the AI's own interpretation. In this way, the keyword framework shifted analytical authority back to the researcher, reducing the risk of undetected semantic drift or misclassification that may occur when AI systems operate without predefined retrieval logic. Unlike conventional keyword searches, which return all passages containing a term regardless of context, the AI-assisted approach enabled contextual filtering, retaining only passages where the keyword appeared in a substantively relevant rather than incidental or generic context. The complete keyword lists and filtering criteria for each theme are provided in the Appendix. These passages were further filtered using the impact scale (Table 2), retaining only content that described concrete actions, targets, or governance mechanisms rather than generic or symbolic language. Gu et al. (2024) have shown that such approaches are effective in extracting regulatory-relevant content from unstructured narrative reports, especially when combined with sector-specific vocabularies and context filters.

The system was implemented using publicly available tools, including the OpenAI interface, ensuring that the approach remains open and repeatable for non-commercial users. This choice also reflects a deliberate balance: while unsupervised techniques such as topic modeling or sentiment analysis may reveal latent structures, they risk producing categories that are not aligned with regulatory frameworks or comparable across companies. By contrast, the rule-based AI approach presented here prioritizes regulatory alignment, transparency, and practical applicability. Within the Design Science Research process, this implementation corresponds to the development phase, in which the manually developed conceptual framework is operationalized into a functional artifact (Geerts, 2011; Peffers et al., 2008).

4. Results

The seven ESG themes identified in this study (Table 3) emerged inductively through qualitative content analysis of sustainability reports and should be understood as analytically derived structures specific to the studied dataset and reporting context rather than a universal ESG taxonomy. The following results illustrate how consistently each theme appeared in practice and demonstrate the framework's ability to organize heterogeneous ESG disclosures into a consistent thematic structure. Because the analysis relies on corporate sustainability disclosures, which may involve selective reporting, the identified themes reflect patterns in reported ESG content rather than a comprehensive representation of actual ESG practices or performance.

A clear emphasis on environmental protection and emissions reduction emerged from the reports. Most reports highlighted the goal of reducing carbon emissions and transitioning to low-carbon fuels, especially in the shipping and energy sectors. Specifically, carbon emission reductions, the use of renewable energy sources, and improving energy efficiency were prominent. While emissions reduction and improving energy efficiency are seen as crucial goals, deeper reporting, such as specific emissions targets or metrics, was often lacking in many reports. Environmental impacts are closely tied to companies' ability to meet regulatory requirements and implement sustainable business solutions, such as using renewable energy sources and energy saving technologies. The framework's ability to surface this gap between general commitment and specific measurable action illustrates its value in making reporting depth systematically visible across companies.

The second theme, ESG Metrics and Monitoring, directly relates to the quality of reporting and data collection. While tracking ESG goals is highly significant, the reports often contain only general references to metrics without a more detailed analysis of how well these targets are being achieved. This aligns with previous findings where the length of a report does not necessarily add depth to its content, leaving many details, such as the concrete impact of metrics and monitoring on business decision-making, unaddressed (Nicolas et al., 2023; Lin et al., 2024; Luccioni et al., 2020). By organizing reporting content under this theme, the framework makes it possible to identify which companies move beyond general metric references toward substantive performance tracking. This distinction would be difficult to detect without a structured analytical approach.

The third theme, Data Reliability and Assurance, appeared less consistently across reports than the other themes, particularly in disclosures related to internal operations and verification processes. Reports focusing primarily on environmental impacts or stakeholder engagement tended to address data reliability less explicitly. This uneven coverage itself represents a meaningful finding. The framework makes such gaps in reporting transparency systematically visible, highlighting which companies treat data assurance as a core reporting element and which address it only peripherally.

Table 3
Inductively Derived ESG Themes and Their Main Reporting Focus.

ESG Theme	Main Reporting Focus
Carbon Footprint & Energy Efficiency Management	Emissions reduction, renewable energy transition, energy efficiency measures, and carbon management practices
ESG Metrics & Monitoring	ESG KPIs, monitoring systems, performance tracking, and reporting structures
ESG Data Reliability & Assurance	Verification practices, assurance processes, audit mechanisms, and ESG data quality
Climate Change Risk Reporting	Climate-related risks, transition risks, resilience planning, and regulatory alignment
Circular Economy & Resource Efficiency	Recycling, waste reduction, resource efficiency, circular economy initiatives, and material use
ESG in Business Governance	ESG oversight, governance structures, board responsibilities, and strategic integration
Stakeholder Impacts	Stakeholder engagement, customer value, employee wellbeing, social responsibility, and external impacts

The fourth theme, Climate Change Risk Reporting, was present in many reports, but it often revolved mainly around regulatory requirements derived from EU or international climate agreements. A deeper analysis of the risks that climate change poses to business operations and how these risks are managed was somewhat lacking. This reflects previous research, which suggests that ESG reporting often focuses more on stakeholder legitimacy and perceptions rather than operational transparency (Nicolas et al., 2023; Lin et al., 2024). The framework's thematic structure makes this distinction visible, separating regulatory compliance language from substantive operational risk disclosure. This enables future analyses to assess the depth of climate risk reporting across firms and sectors.

The fifth theme, Circular Economy & Resource Efficiency, was present in many reports, but its treatment was often superficial or at a general level. Resource efficiency is an essential part of a company's environmental responsibility, but reports contained fewer concrete details on how companies are advancing circular economy practices. Reporting on this theme was often limited to general references, with fewer concrete examples related to recycling metrics or reuse practices. This pattern suggests that circular economy practices remain an underdeveloped area in current ESG disclosure, and the framework provides a structured basis for identifying which companies move beyond general commitments toward concrete and measurable circular economy reporting.

The sixth theme, ESG in Business Governance, emerged mainly in introductory sections, and in most reports, it remained superficial. While the board and ESG committees were mentioned, there was insufficient reporting on practical leadership responsibilities, such as performance-based rewards or executive accountability in ESG matters. The framework makes this structural pattern visible, distinguishing between governance structures that are formally mentioned and those that are substantively integrated into business decision-making. This provides a basis for identifying meaningful variation in governance reporting across companies.

The seventh theme, Stakeholder Impacts, was widely represented across the reports, particularly in discussions concerning customer value creation, employee wellbeing, occupational safety, and stakeholder engagement. Companies frequently emphasized collaboration with customers, suppliers, employees, and local communities as part of their broader sustainability strategies. However, the depth of reporting varied considerably across sectors and firms. In many cases, stakeholder-related reporting focused primarily on general commitments and engagement initiatives, while fewer reports provided concrete examples of how stakeholder considerations were integrated into operational decision-making, performance measurement, or long-term strategic planning. This variation in reporting depth across firms and sectors illustrates how the framework makes differences in reporting emphasis more transparent, providing a basis for identifying which companies integrate stakeholder considerations into operational decision-making and which address them only at a general level.

4.1. Sectoral differences in ESG reporting

Although reports across all sectors addressed the same seven ESG themes, the emphasis and depth of reporting varied systematically across industries. These variations reflected differences in operational contexts, stakeholder expectations, regulatory exposure, and business models. While CSRD and ESRS aim to harmonize sustainability reporting practices, the reports demonstrated clear sector-specific differences in how ESG issues were prioritized and communicated.

In the automotive and manufacturing sectors, climate targets, emissions reduction, and technological transition strategies were particularly emphasized. Companies frequently reported Scope 1–3 emissions targets, electrification initiatives, energy-efficiency measures, and material recycling practices. ESG metrics and monitoring systems were often externally assured, reflecting the sectors' strong regulatory exposure and operational focus on measurable environmental performance. Social and stakeholder-related themes were generally discussed less extensively than environmental disclosures.

In the energy sector, climate transition strategies and risk management dominated the reporting. Companies frequently referred to frameworks such as the EU Taxonomy, ESRS, and TCFD, while emphasizing renewable energy investments, energy security, and transition planning. Reporting in this sector was typically technical and risk-oriented, whereas stakeholder and social responsibility topics were often addressed in broader and less operational terms.

In contrast, consumer-focused industries emphasized supply chain responsibility, customer relationships, and stakeholder engagement. These reports frequently discussed responsible product portfolios, data privacy, and human capital development. ESG themes were typically integrated into strategic KPIs, and double materiality was often visualized. Reports in this category were aligned with both GRI and ESRS standards. Social themes were more pronounced here than in most other sectors.

In the construction and infrastructure industries, climate and material issues were the most prominent. Companies frequently reported on resource efficiency, occupational safety, and alignment with international climate targets. Some reports included workforce development and equality metrics, while others focused more on governance structures such as ESG committees and internal audit processes than on results-based metrics.

These sectoral findings illustrate how the same thematic framework surfaces different reporting priorities depending on industry context. Technology and manufacturing sectors prioritized emissions and technical solutions, consumer sectors highlighted stakeholder impact and social issues, and energy and infrastructure sectors focused on climate risk and compliance structures (e.g., EU Taxonomy, TCFD, ESRS). These differences became visible when the same thematic framework was applied consistently across all analyzed reports.

4.2. Tests using artificial intelligence

The analysis identified over 27,000 text segments related to the seven ESG themes. On average, each report contained approximately 115 thematically classified segments, around 16 per theme, although this number varied significantly depending on report length, industry, and structural layout. The most frequently observed themes were Carbon Footprint & Energy Efficiency Management

(present in 93% of reports), ESG Metrics and Monitoring (88%), and Stakeholder Impacts (85%). Less frequently observed but still significant were Climate Risk Reporting (62%) and Data Assurance and Reliability (59%). These findings indicate that ESG reporting tends to emphasize outward-facing themes, such as emission reductions, stakeholder communication, and social impact. Meanwhile, more internally focused topics, such as risk management and verification, are reported less consistently. This trend aligns with earlier research indicating that ESG disclosures often prioritize legitimacy and stakeholder perception over operational transparency and verifiability (Nicolas et al., 2023; Lin et al., 2024; Luccioni et al., 2020).

In this comparison, manually coded data served as the interpretive reference against which the performance of keyword-only and AI-assisted approaches was assessed. The comparison therefore concerns thematic recovery and classification consistency relative to the manually coded baseline, rather than against an objective ground truth. The comparative evaluation showed that keyword-only searches resulted in a high number of false positives, such as template language and illustrative examples lacking substantive content. This reflects a common issue in traditional ESG search techniques, where keyword presence alone does not establish thematic relevance. In contrast, combining keywords with theme-specific context filters significantly improved both accuracy and coverage (Table 4). The combined use of keywords and contextual filtering reduced false positives compared to keyword-only searches. For example, while the term “assurance” frequently appeared in reports, only passages that mentioned third-party audits or verified processes were counted as valid for Theme 3.

The recall estimates in Table 4 are based on a validation subset of 200 randomly sampled AI-extracted passages, drawn across all seven ESG themes and multiple industry sectors to ensure variation in reporting style and content. Each passage was compared against the corresponding manually coded reference data to evaluate whether the AI-assigned theme matched the manual interpretation and whether the extracted content was substantive rather than generic or templated. In cases where discrepancies or ambiguities were detected, coding decisions were reviewed and resolved iteratively, refining both the keyword sets and AI prompts. All validation steps were conducted by the primary researcher, ensuring consistency with the original manual coding logic. The estimates therefore reflect qualitative approximations of thematic detection consistency rather than formal statistical measures. As validation was performed by a single researcher, inter-rater reliability could not be formally assessed; future applications of the framework would benefit from independent coding by a second researcher to further strengthen reliability.

These findings support previous research emphasizing the value of semantically guided, context-aware technologies in ESG analytics (Ranta et al., 2023). The strong consistency between manually coded segments and AI-detected content reinforces the method's reliability. Additionally, the hybrid model's ability to filter out symbolic or generic statements improves the integrity of the resulting data. This helps ensure that the extracted content represents substantively relevant ESG information rather than merely structural or generic text.

4.3. Reliability

The accuracy and reliability of the AI-assisted method were evaluated by comparing the AI-generated classifications with manually coded reference data. The ESG reports of the 52 companies included in the manual phase (104 reports in total) were reanalyzed using the AI model, and the results were compared with the original manual coding outcomes. The findings showed strong consistency between the manually coded reference material and the AI-assisted classifications, with near-complete recovery of manually identified themes within the validation subset. It is important to note that the manually coded data served as the interpretive baseline of the study rather than as an objective ground truth.

In addition, the passage-level validation further showed that approximately 88–92% of sampled passages were classified consistently with the manually coded thematic interpretation, indicating a high level of thematic classification consistency while still leaving room for improvement in cases of semantic ambiguity. The AI-assisted process also retrieved additional relevant passages within appendices, tables, and technical sections that were less consistently identified during manual review due to their structural complexity.

Some limitations were nevertheless observed during the AI-assisted classification process. Stakeholder-related references were occasionally classified under governance themes, particularly when executive responsibility was discussed without clear thematic context. Similarly, general statements such as “this report follows GRI” were at times identified as assurance-related content despite the absence of explicit audit or verification processes. Such misclassifications are consistent with previous research highlighting the challenges posed by semantic ambiguity and templated ESG language for large language models (Gu et al., 2024; Luccioni et al., 2020). Overall, the results suggest that AI can apply the manually developed thematic framework with a high degree of consistency while

Table 4
Comparative Thematic Recovery by Method.

Method	Approximate Recall (%)	Description
Context only search	40–60%	Relies on broad semantic matches (e.g., “ESG”, “climate”), often misses technical or quantified disclosures
Manual thematic coding	85–95%	Based on human reading and thematic coding; varies by reader expertise and report complexity
AI + keyword + filter model	95–100%	Recovered all manually identified themes and found additional relevant passages

Recall (%): Qualitative approximation based on performance of different methods across a validation subset, compared by theme coverage, segment count, and depth.

preserving the interpretive structure established during manual analysis.

5. Conclusion

Sustainability reports are often long, complex, and poorly standardized, making it difficult to extract meaningful and comparable information across companies. This study introduced a transparent and replicable methodological framework that addresses this challenge by organizing heterogeneous ESG disclosures into structured thematic summaries through a two-stage process: manual inductive coding followed by AI-assisted scaling across a larger dataset.

The study contributes to ESG reporting research in three ways. Theoretically, it advances understanding of how inductive qualitative interpretation can be combined with AI-assisted retrieval to organize sustainability disclosures without relying on opaque scoring mechanisms. Methodologically, it introduces a replicable two-stage framework in which manually derived themes establish the interpretive foundation and AI enables consistent application across larger datasets, offering a transparent alternative to commercial ESG rating methodologies. Practically, the framework produces structured thematic profiles showing which ESG topics are addressed, how extensively, and at what level of specificity, information that investors, analysts, and regulators can begin to use and interpret in a manner of their choosing.

Several limitations should be acknowledged. Classification outcomes remain sensitive to semantic ambiguity, prompt design, and variation in reporting structures (Brown et al., 2020; Barredo Arrieta et al., 2020). Complex report formats such as tables, appendices, and scanned documents may affect text extraction (Gu et al., 2024). Furthermore, because the analysis relies on corporate disclosures, the identified themes reflect patterns in reported ESG content rather than actual ESG practices or performance.

Future work could extend the framework toward quantitative profiling, where the thematic structures developed here serve as the basis for scoring and statistically comparing companies' ESG reporting practices. Longitudinal application would enable systematic tracking of how CSRD implementation shapes disclosure practices over time. The framework may also support regulatory bodies in monitoring ESRS adoption across industries and jurisdictions and could be extended beyond the EU context to support comparative ESG research in broader international settings.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Appendix

Examples of keywords used in the prompt.

THEME 1: Carbon Footprint & Energy Efficiency Management

Keywords:

CO₂ emissions, co2 emissions, carbon footprint, GHG emissions, greenhouse gas emissions, ghg, emissions intensity, emission intensity, energy intensity, Scope 1 emissions, Scope 2 emissions, Scope 3 emissions, scope 1, scope 2, scope 3, emission reduction, emission reduction targets, decarbonization, decarbonization roadmap, net zero, net zero, carbon neutrality, climate neutrality, carbon emissions decreased, our carbon intensity improved, reduced CO₂, reduced emissions, energy efficiency, energy consumption, energy use, energy management, Energy Efficiency Directive, ISO 50001, energy audits, renewable energy, renewable electricity, self-generated electricity, solar panels, biomass boilers, electrification, heat pump, waste heat recovery, smart sensors, hyper efficient ventilation, energy KPIs, energy performance indicators, carbon roadmap, decarbonize, GHG target, emission KPI, low-carbon, ISO-standardized audits, energy saving program, climate neutrality plan, decarbonisation, low-carbon, carbon intensity, Green Electricity, energy transition, fossil free, fossil-free energy, carbon neutral, carbon neutral operations, emissions factor, emissions baseline, ISO 14064, SBTi (Science Based Targets initiative), GHG Protocol, energy intensity reduction, renewable PPAs, electrification of fleet, biogenic CO₂, carbon handprint, decarbonization levers, electrical efficiency programs, energy transition pathway, green fuel adoption, low-carbon technologies, carbon accounting, carbon emissions inventory, emissions tracking tool, fleet electrification, hydrogen powered vehicles, low-carbon procurement, renewable gas, e-fuels, green hydrogen, solar farm, onsite solar generation, energy use intensity, CO₂e, avoided emissions, decarbonization enablers, net zero pathway, climate action plan, emission factor database, certified green electricity.

Filtering Criteria

1. Quantitative emissions or energy metric, target, or realized reduction
2. Action, solution, or transition related to energy or emissions
3. Discussion of energy or emissions in risk, regulatory, or business impact context
4. Reference to standards, certifications, or emissions data methodologies

5. Product level design principles or technology shifts relevant to carbon or energy

THEME 2: ESG Metrics & Monitoring

Keywords:

ESG metrics, ESG metric, KPI, KPIs, key performance indicators, performance indicator, performance indicators, measures, indicator, indicators, metrics tracking, metric tracking, tracking, monitoring, monitor, real time monitoring, Realtime monitoring, dashboard, dashboards, sustainability dashboard, scorecard, scorecards, reporting, report, reports, data analytics, analytics, charts, graphs, plots, tables, figures, data visualization, visualization, benchmarking, benchmark, comparative analysis, comparative analyses, target setting, target settings, portal, platform, application, system, tool, scorecard, tracking system, sustainability platform, internal dashboard, ESG application, KPI database, metrics governance, sustainability indicators, ESG framework, ESG standards, data reporting system, GRI index, SASB, CSRD, ESG disclosure, performance dashboard, materiality assessment, ESG progress, double-materiality, ESG data architecture, sustainability KPI, ESG heatmap, ESG performance score, sustainability index rating, digital ESG cockpit, KPI performance review, materiality heatmap, ESG data lake, environmental metrics consolidation, double-materiality matrix, ESG indicator mapping, sustainability control tower, ESG data warehouse, integrated reporting platform, automated sustainability reporting, dynamic KPI dashboard, ESG performance pulse, metric visualization tools, KPI harmonization, ESG metrics catalogue, ESG tracking engine, regulatory reporting modules, score improved, benchmarking, real time dashboard, scorecard includes.

Filtering Criteria

1. Quantitative reference to ESG metrics, performance indicators, or targets
2. Mention of tracking process or tool in a concrete way
3. Use of a system or tool in the context of visualization or reporting
4. Description of centralized or digital platforms for ESG data management
5. Mention of external benchmarking, dashboards, or analytics platforms
6. Reference to indirect indicators related to ESG measurement or systems

THEME 3: ESG Data Reliability & Assurance

Keywords:

data validation, verification, verify, verifies, verified, review, reviews, review process, audit, audits, auditing, audit trail, attestation, assurance, external assurance, limited assurance, reasonable assurance, assurance provider, assurance scope, sustainability assurance, verification statement, verification report, verification protocol, ISAE 3000, ISAE 3402, AA1000, GRI assurance, certification, assurance standard, quality, accuracy, consistency, internal controls, control framework, quality control, data control, reporting integrity, audit procedure, internal validation, verified indicators, third party checks, independent assurance, audit findings, ESG controls, control environment, external review, third party validation, verified emissions, audit trail documentation, limited assurance engagement, accuracy of disclosures, nonfinancial assurance, third party ESG data verification, limited assurance for nonfinancial data, AA1000AS, audit of sustainability KPIs, data governance for ESG, external ESG audit, GRI-certified assurance, assurance scope statement, data integrity controls, nonfinancial data assurance, assurance of Scope 3 emissions, external ESG data certification, sustainability audit framework, data reliability statement, ESG data traceability, certified assurance provider, assurance readiness, verification of ESG disclosures.

Filtering Criteria

1. Mention of assurance or audit process related to sustainability or nonfinancial reporting
2. Reference to recognized assurance standards or frameworks
3. Description of internal controls or quality structures for ESG data
4. Third party involvement or named assurance provider
5. Mentions of audit trail, validation systems, or ESG data quality monitoring

THEME 4: Climate Related Risk Reporting

Keywords:

climate risk reporting, TCFD, scenario analysis, stress testing, physical climate risks, transition risks, acute risks, chronic risks, risk and opportunity identification, risk disclosure, resilience, resilience metrics, adaptation measures, mitigation measures, vulnerability assessment, SSP, RCP, IPCC, hazard identification, risk matrix, adaptation strategy, mitigation strategy, climate scenario, flood risk, extreme weather, heatwave, long-term resilience, TCFD-aligned, climate adjusted strategy, climate related financial disclosure, climate stress test, climate adaptation, temperature alignment, climate impact modeling, low-carbon transition, sustainability risks, financial risk from climate, climate-related impact assessment, climate risk mapping, climate vulnerability mapping, transition risk modeling, physical climate exposure, TCFD gap analysis, climate alignment scenarios, RCP-aligned assumptions, climate scenario coverage, resilience risk testing, climate resilience plan, physical climate vulnerability, carbon transition exposure, low-carbon economy scenario, net zero transition risks, regulatory transition risk, business model resilience, heatmap of climate exposure,

TCFD alignment matrix, cross sectoral scenario analysis.

Filtering Criteria

1. Reference to scenario analysis or scientific climate frameworks
2. Identification of climate related risks and opportunities
3. Description of adaptation or mitigation strategies
4. Descriptions of risk tables, matrices, or documentation tools
5. General resilience planning, transition risk management, or extreme weather preparedness

THEME 5: Circular Economy & Resource Efficiency

Keywords:

circular economy, life cycle assessment (LCA), resource efficiency, material efficiency, waste reduction, waste management, zero waste, landfill diversion, recycle, recycled, recycling, reuse, remanufacturing, upcycling, packaging reduction, optimization, water stewardship, water recycling, biodiversity, ecosystem services, nature based solutions, regenerative agriculture, ecosystem restoration, habitat preservation, IBA, ISO 14001, ISO 20400, Ellen MacArthur Foundation, EU Circular Economy Action Plan, material circularity, packaging redesign, renewable coating, sustainable fiber, composability, reusability, molded fiber, eco efficiency, lifecycle thinking, reuse of materials, closed loop systems, cradle to cradle, zero landfill, recycling programs, design for environment, secondary materials, sustainable materials, Environmental Footprint, raw material efficiency, material circularity indicator, eco design principles, end of life recovery, design for recyclability, post-consumer recycled content, circularity index, resource decoupling strategy, plastic reduction roadmap, biodiversity action plan, regenerative design, sustainable packaging initiative, closed loop recycling system, industrial symbiosis, cradle to gate, recycled input materials, circular procurement policy, waste valorization, packaging take back scheme, bio based packaging, water circularity.

Filtering Criteria:

1. Description of circular economic principles, life cycle thinking, or life cycle assessment (LCA)
2. Waste, recycling, or material efficiency actions
3. Water resource management or efficiency initiatives
4. Actions related to protecting biodiversity or ecosystem services
5. References to ESG-related standards or recognized frameworks
6. Indirect indicators such as eco design, packaging optimization, or stewardship programs

THEME 6: ESG in Business Governance

Keywords

corporate governance, ESG governance, board of directors, audit committee, sustainability advisory committee, executive committee, ESG integration, strategy integration, governance KPIs, nonfinancial reporting, external assurance, whistleblowing, grievance mechanism, board diversity, integrity policies, ESG oversight, board responsibility, ethics channel, governance KPI, nonfinancial audit, strategic alignment, ESG committee, sustainability governance, ESG charter, board oversight of ESG, compliance with ESG policy, ESG integration in strategy, risk committee ESG, board ESG training, ethical governance, ESG oversight structure, sustainability linked compensation, ESG competency matrix, board ESG training program, governance scorecard, remuneration, ethics and compliance hotline, executive ESG responsibility, ESG escalation protocol, sustainability committee mandate, sustainability steering committee, ESG governance roadmap, board ESG competency, ESG-linked incentive model, ethics hotline management, ESG compliance tracking, ESG escalation framework, cross functional ESG team, ESG accountability structure, executive ESG scorecard.

Filtering Criteria:

1. ESG connection to governance structures, committees, or formal oversight functions
2. ESG inclusion in business strategy or management systems
3. Governance performance metrics or accountability mechanisms
4. ESG reporting structures or assurance practices tied to governance
5. References to board level oversight, diversity policies, or ethics mechanisms

THEME 7: Stakeholder Impacts

Keywords:

customer engagement, investor relations, stakeholder engagement, brand value, intangible assets, community engagement, DEI, employee engagement, human rights due diligence, living wage, NGO partnerships, employee wellbeing, customer satisfaction, partner dialogue, inclusive hiring, human rights audit, DEI training, engagement survey, social impact, employee inclusion, worker voice, community relations, human rights assessment, diversity and belonging, staff surveys, social responsibility, workplace wellbeing, employee value proposition, stakeholder mapping, social value creation, employee engagement index, inclusive growth strategy, community investment program, wellbeing strategy, employee net promoter score, social return on investment, supplier

diversity program, employee advocacy, stakeholder listening program, inclusive workplace strategy, ESG dialogue sessions, social listening tools, employee impact survey, supplier social audit, employee net satisfaction, stakeholder engagement journey, community value creation plan.

Filtering Criteria

1. Stakeholder involvement, dialogue, or interaction
2. Statements about brand, reputation, or intangible value
3. Implementation of social responsibility or DEI (diversity, equity, inclusion) policies
4. Human rights due diligence or supplier responsibility frameworks
5. References to NGO partnerships, public programs, or employee engagement actions

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