EVALUATING ESG SOFTWARE SOLUTIONS FOR SUSTAINABILITY REPORTING IN THE MANUFACTURING SECTOR

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Abstract:
The Corporate Sustainability Reporting Directive (CSRD) introduces stringent and standardised environmental, social, and governance (ESG) reporting obligations across the European Union, presenting significant challenges for manufacturing companies due to their resource-intensive operations and complex value chains. This study investigates the digital transformation of sustainability reporting by evaluating how ESG software tools support CSRD compliance. A comparative analysis was conducted on eight widely used ESG software solutions. Thirteen assessment criteria were applied, covering functionality, regulatory compliance, integration capabilities, cost transparency, and scalability. The role of artificial intelligence and advanced analytics in enhancing ESG data quality, automating reporting processes, and generating actionable insights is also explored as a critical enabler of reporting efficiency and accuracy. The findings show that while no tool meets all needs universally, specific solutions offer comprehensive capabilities for large manufacturers, while others are well-suited for SMEs. The study concludes with targeted software selection recommendations and outlines future research directions.

Key words: ESG software, CSRD, ESRS, manufacturing sector, sustainability reporting, ESG digital tools, non-financial reporting, software comparison, AI

INTRODUCTION

The Corporate Sustainability Reporting Directive (CSRD), which came into force in January 2023, represents a paradigmatic shift in sustainability reporting requirements across the European Union. This directive significantly expands the scope and depth of non-financial reporting obligations, moving beyond the previous Non-Financial Reporting Directive (NFRD) to encompass a broader range of companies and more comprehensive reporting standards [1, 2]. For manufacturing companies, the CSRD presents both unprecedented opportunities for demonstrating sustainability leadership and substantial implementation challenges that require strategic organisational transformation.

The manufacturing sector, characterised by resource-intensive production processes, complex global supply chains, and significant environmental footprints, faces particular challenges in meeting the CSRD's stringent requirements [3]. The directive's emphasis on double materiality, comprehensive stakeholder engagement, and detailed environmental, social, and governance (ESG) disclosures necessitates fundamental changes in how manufacturing companies collect, analyse, and report sustainability data [4, 5].

As the demand for standardised, verifiable, and decision-useful ESG data increases, software solutions are emerging as essential tools to support reporting activities, risk assessment, and regulatory compliance. These systems differ in their level of maturity, functional scope, scalability, and alignment with standards, which poses a critical challenge for manufacturing companies when selecting appropriate technological support for CSRD implementation.

In response to these challenges, this article seeks to answer three research questions: (1) What are the core functionalities of ESG software solutions that are critical for compliance with the CSRD in the manufacturing sector? (2) How do different ESG tools vary in terms of their support for GHG emissions tracking (Scope 1, 2, and 3), supply chain monitoring, and alignment with global reporting standards (e.g., GRI, TCFD, ESRS)? (3) Which ESG software solutions are most suitable for small, medium, and large manufacturing companies, considering their technical, financial, and operational capabilities?

The structure of the article is as follows. The next section presents a literature review that explores three thematic areas: the key requirements of the CSRD, specific reporting challenges faced by manufacturing companies, and

the role of digital solutions in supporting ESG reporting processes. Section three outlines the adopted research methodology, including the selection of comparison criteria and the scope of the evaluated ESG tools. Section four presents the results of the comparative analysis, highlighting functional differences and degrees of regulatory alignment among the tools. Section five develops practical recommendations tailored to various company types, taking into account size, emissions focus, and supply chain complexity. Finally, section six provides conclusions, identifies limitations of the study, and suggests directions for future research.

KEY REQUIREMENTS OF THE CORPORATE SUSTAINABILITY REPORTING DIRECTIVE

The Corporate Sustainability Reporting Directive (CSRD), adopted by the European Union in 2022, introduces a transformative expansion in the scope and detail of sustainability reporting for companies operating within the European Union. It amends the existing Non-Financial Reporting Directive (NFRD) and addresses its identified shortcomings in terms of comparability, reliability, and accessibility of sustainability-related information [7]. The CSRD significantly broadens the coverage of sustainability reporting obligations. Whereas the NFRD applied to approximately 11,600 companies, the CSRD is expected to encompass around 50,000 companies across the EU [1]. This change reflects the EU's aim to mainstream sustainability disclosure across a wider range of economic actors. The scope of the CSRD includes the following categories of undertakings [7]:

- Large undertakings (both listed and non-listed) that meet at least two of the following criteria:
  - More than 250 employees,
  - More than €40 million in net turnover,
  - More than €20 million in total assets.
- Listed SMEs, except micro-enterprises (i.e., companies with fewer than 10 employees and less than €2 million in turnover or total assets), are subject to reporting obligations starting in 2026, with an option to opt out until 2028 (see Figure 1).
- Non-EU companies with a net turnover of more than €150 million in the EU and at least one subsidiary or branch within the EU exceeding certain thresholds will also be required to publish sustainability reports aligned with the CSRD from 2028 onward.
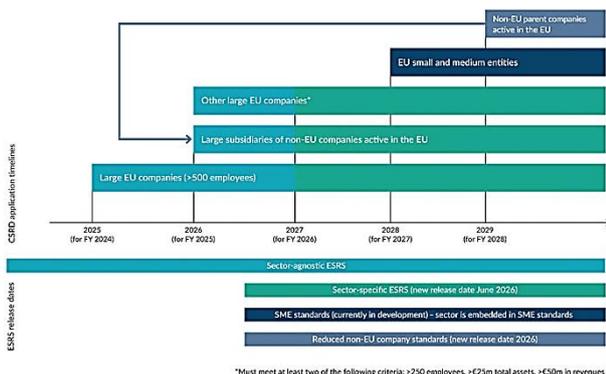
Fig. 1 Timeline of CSRD compliance
Source: [18].

This extensive scope reflects the EU's intention to ensure comprehensive and harmonised sustainability reporting across both the public and private sectors, as well as among EU-based and globally active businesses [2].

The CSRD mandates the use of detailed and standardised European Sustainability Reporting Standards (ESRS), developed by the European Financial Reporting Advisory Group (EFRAG). These standards aim to harmonise reporting across entities, ensuring consistency, comparability, and forward-looking disclosures related to environmental, social, and governance (ESG) aspects [7, 8]. The standards include sector-agnostic and sector-specific modules and emphasise both double materiality and value chain transparency [5].

A key conceptual foundation of the CSRD is the double materiality principle. Companies must disclose both:

- how sustainability issues affect their financial performance (financial materiality),
- and how their operations impact society and the environment (impact materiality).

This dual lens reflects the EU's shift from a shareholder-centric model toward a stakeholder-oriented accountability framework [4, 9].

Moreover, the CSRD requires sustainability reports to be digitally tagged using XHTML and XBRL formats, which are machine-readable and allow for automated data extraction and cross-company comparison by investors, regulators, and analysts [6, 11, 12]. This digital taxonomy aligns with the EU's Digital Finance Strategy and aims to facilitate the integration of ESG data into mainstream financial analysis.

Regarding the assurance issues, unlike the NFRD, the CSRD introduces an audit requirement for sustainability reports. Companies will be required to seek limited assurance on reported information initially, moving gradually toward reasonable assurance as standards and capacities evolve [13, 14, 15]. This will significantly enhance the credibility and trustworthiness of sustainability data presented to stakeholders. The directive also stipulates that sustainability disclosures must be embedded within the management report of a company rather than presented separately. This obligation should ensure that sustainability is integrated into the core strategic narrative of the business and not treated as a peripheral issue [16, 17].

SPECIFIC CHALLENGES FOR MANUFACTURING COMPANIES IN SUSTAINABILITY REPORTING (SR)

Manufacturing companies face specific challenges in SR reporting, and each of them is discussed in the following subsections.

Environmental Reporting Challenges

Manufacturing companies face substantial challenges in meeting the CSRD's environmental reporting requirements, which are significantly more comprehensive than previous obligations [8]. The directive requires detailed disclosure of environmental impacts across the entire value chain, including Scope 1, 2, and 3 greenhouse gas emissions. For manufacturing companies, Scope 3

emissions often represent the largest portion of their carbon footprint, encompassing upstream supplier activities and downstream product use and disposal [19]. The implementation of environmental reporting under the CSRD requires manufacturing companies to establish robust data collection systems capable of capturing granular environmental metrics at the facility, process, and product levels [5]. This necessitates significant investments in monitoring technologies, data management systems, and analytical capabilities [11, 20]. Many manufacturing companies struggle with data availability and quality, particularly for Scope 3 emissions, where reliance on supplier-provided information introduces additional complexity and uncertainty [21, 22].

Water usage and management represent another critical area where manufacturing companies must enhance their reporting capabilities. The CSRD requires detailed disclosure of water consumption, water stress assessments, and water-related risks across operations and supply chains [8]. For water-intensive manufacturing processes, this may necessitate the implementation of advanced water monitoring systems and collaboration with suppliers to obtain comprehensive data on water usage [23].

Waste and circular economy reporting under the CSRD presents additional challenges for manufacturing companies. The directive requires disclosure of waste generation, treatment methods, and circular economy initiatives, including material recycling rates and product design for circularity [19]. Thus, manufacturing companies need to develop systems to track material flows throughout their operations and establish metrics for measuring progress toward circular economy objectives.

Social and Governance Reporting Implications

The CSRD's social reporting requirements present unique challenges for manufacturing companies, particularly those with global operations and complex supply chains. The directive requires comprehensive disclosure of workforce-related metrics, including diversity and inclusion, working conditions, health and safety, and skills development [15]. For manufacturing companies with significant blue-collar workforces, this may require enhanced data collection systems to capture detailed workforce demographics and working condition metrics. Supply chain social responsibility reporting represents a particularly complex challenge for manufacturing companies. The CSRD requires disclosure of due diligence processes for identifying and addressing social risks in supply chains, including forced labour, child labour, and unsafe working conditions [6, 17]. Manufacturing companies are forced to establish robust supplier assessment and monitoring systems, often requiring engagement with multiple tiers of suppliers across diverse geographic regions with varying regulatory environments.

Governance reporting under the CSRD requires manufacturing companies to disclose detailed information about their sustainability governance structures, risk management processes, and stakeholder engagement mechanisms [13]. This includes disclosure of board-level oversight of sustainability matters, integration of sustainability considerations into executive compensation, and processes for stakeholder consultation and grievance handling.

Double Materiality Assessment Challenges

The CSRD's double materiality principle requires companies to assess both their impacts on society and the environment (impact materiality) and how sustainability matters affect their financial performance (financial materiality) [4, 9]. Conducting comprehensive double materiality assessments could present significant methodological and practical challenges. Impact materiality assessments require manufacturing companies to evaluate their effects across the entire value chain, including upstream supplier activities and downstream product use. This necessitates sophisticated analytical capabilities to quantify environmental and social impacts, often requiring life cycle assessment methodologies and stakeholder engagement processes [24, 25]. Financial materiality assessments require evaluating how sustainability matters could affect their financial performance over short, medium, and long-term time horizons. This includes assessing physical and transition risks related to climate change, regulatory risks associated with environmental compliance, and reputational risks related to social and governance issues. These assessments should be integrated into their enterprise risk management frameworks and financial planning processes [13].

Data Management and Digital Infrastructure Challenges

The CSRD's requirement for digital tagging of sustainability information using the European Single Electronic Format (ESEF) presents significant technical challenges for companies [10]. Companies often struggle with data integration challenges, as sustainability data is frequently scattered across multiple operational systems, including enterprise resource planning (ERP) systems, manufacturing execution systems (MES), and environmental management systems [11, 21]. The CSRD requires integration of this disparate data into coherent sustainability narratives, necessitating significant investments in data management infrastructure and analytical capabilities. Data quality and assurance represent additional challenges. The directive requires external assurance of sustainability information, initially at a limited level but progressing to reasonable assurance over time. This requirement imposes on companies to establish internal controls and documentation systems sufficient to support external audit processes, often requiring significant changes to existing data collection and validation procedures [22].

Supply Chain Engagement and Due Diligence

Manufacturing companies could face particular challenges in engaging their supply chains to obtain the data necessary for comprehensive CSRD reporting. The directive's value chain reporting requirements necessitate collection of detailed environmental and social data from suppliers, often extending beyond direct suppliers to

include multiple tiers of the supply chain [5, 6]. Supplier engagement strategies must account for the diverse capabilities and resources of supply chain partners, particularly smaller suppliers that may lack sophisticated sustainability reporting systems [26].

Due diligence reporting under the CSRD requires companies to disclose their processes for identifying, assessing, and addressing sustainability risks in their supply chains. This includes disclosure of supplier assessment criteria, monitoring mechanisms, and remediation processes for addressing identified issues. In meeting these disclosure obligations, companies must balance transparency requirements with commercial sensitivities and competitive considerations [25].

Integration with Existing Management Systems

Manufacturing companies often have established management systems (EMS) based on ISO 14001 and other standards, e.g. ISO 9001 or ISO 45001, which provide a foundation for CSRD implementation but require significant enhancement to meet the directive's comprehensive requirements [3]. The integration of CSRD reporting with existing management systems presents both opportunities for leveraging established processes and challenges in adapting these systems to meet new requirements [15].

Stakeholder Engagement and Communication Challenges

The CSRD requires manufacturing companies to engage with a broad range of stakeholders in their materiality assessments and ongoing sustainability reporting processes [9]. For manufacturing companies with global operations, this may include diverse stakeholder groups across multiple jurisdictions, each with different expectations and communication preferences [25]. This requirement implies that companies should develop stakeholder engagement strategies that account for the technical complexity of their operations while ensuring accessibility and transparency for non-technical stakeholders. This includes developing communication materials that effectively convey complex environmental and social information to investors, customers, communities, and other stakeholder groups [5].

Cost and Resource Implications

Implementation of CSRD requirements represents a significant financial investment for companies, encompassing costs for system development, data collection, external assurance, and ongoing reporting processes [11, 27]. Initial implementation costs may be particularly substantial for companies that lack existing sustainability reporting infrastructure [28]. Manufacturing companies must allocate human resources for CSRD implementation, including sustainability professionals, data analysts, and project managers. The technical complexity of manufacturing

operations often requires specialised expertise to develop appropriate metrics and reporting methodologies. Ongoing compliance costs include external assurance fees, system maintenance, and continuous improvement of reporting processes. Manufacturing companies must factor these costs into their long-term financial planning and consider the potential return on investment through improved stakeholder relationships, risk management, and operational efficiency [16, 17].

SUPPORTING SUSTAINABILITY REPORTING WITH SOFTWARE SOLUTIONS

The implementation of the Corporate Sustainability Reporting Directive (CSRD) has created a demand for software solutions capable of managing the complex data requirements and reporting obligations. For manufacturing companies, which face particularly complex sustainability challenges due to their resource-intensive operations, global supply chains, and significant environmental footprints, the selection and implementation of appropriate software solutions has become a strategic imperative [2, 10, 16, 18, 29].

In this context, artificial intelligence (AI) and advanced analytics are emerging as key enablers of more efficient, accurate, and insightful sustainability reporting. Table 1 outlines how these technologies can support specific ESG reporting activities by enhancing data quality, automating processes, and generating strategic insights.

The digitalization of sustainability reporting represents a fundamental shift from traditional, manual reporting processes to automated, integrated systems capable of capturing, processing, and analysing vast amounts of environmental, social, and governance (ESG) data in real-time [20, 30, 32, 34, 35, 36]. This transformation is particularly critical for manufacturing companies, where sustainability data is often distributed across multiple operational systems, including enterprise resource planning (ERP) systems, manufacturing execution systems (MES), and environmental management systems (EMS). The CSRD requirement for digital tagging and machine-readable reporting formats further emphasises the need for technological solutions that can bridge the gap between operational data and regulatory compliance requirements [10, 31, 37].

Reporting Activity	Activity Description	AI & Advanced Analytics Enhancement	Enhancement Description
Internal data reviews	Systematic checks of raw ESG data for completeness, consistency and anomalies.	Automated anomaly detection	Machine-learning models scan large ESG data sets to flag outliers, missing values or inconsistent entries in real time, reducing manual review effort.
Gap analysis	Comparing current ESG disclosures against standards or peer benchmarks to identify reporting deficiencies.	Predictive benchmarking	AI models ingest both internal data and external peer/benchmark datasets to predict where gaps are likely, and recommend specific metrics to prioritize.
Stakeholder interviews	Collecting qualitative input from investors, NGOs, employees and other ESG stakeholders.	NLP-powered sentiment & theme analysis	Natural-language-processing pipelines transcribe and analyze interview transcripts to extract sentiment trends, recurring concerns and emerging ESG themes.
Data collection	Gathering quantitative and qualitative ESG data from multiple internal systems and external sources.	Intelligent data extraction	Advanced analytics agents connect to ERPs, sensors, public databases and scrape public disclosures, automatically ingesting and normalizing ESG data streams.
Report generation	Assembling finalized ESG reports in line with required frameworks (e.g. GRI, SASB, TCFD).	Automated narrative & visualization generation	AI generates draft narrative sections based on underlying data, and auto-builds charts and dashboards, cutting drafting time.
Materiality assessment & KPI identification	Determining which ESG issues are most relevant to the business and defining the KPIs to measure them.	Data-driven materiality scoring	Machine-learning algorithms correlate stakeholder priorities, industry data and company performance to score and rank material ESG topics objectively.
Performance benchmarking	Comparing a company's ESG performance against industry peers and historical results to gauge progress.	Advanced peer-group analytics	AI clusters peers by size, region and sector, then runs multivariate analyses to highlight areas of relative strength or weakness in ESG performance.

Source: based on [30, 31, 32, 33].

The most important software functionalities supporting Sustainability Reporting should include:

- Data Integration and Automation. Manufacturing companies generate vast amounts of operational data that can be leveraged for sustainability reporting. Advanced software solutions provide automated data collection capabilities that can integrate with existing manufacturing systems [38].
- Supply Chain Management. Given the complexity of manufacturing supply chains and the CSRD\'s emphasis on value chain reporting, software solutions must provide robust supply chain mapping and monitoring capabilities. This includes supplier assessment tools, automated data collection from suppliers, and risk assessment algorithms that can identify potential ESG issues throughout the supply chain [39].
- Emissions Calculation and Management: Manufacturing companies require emissions calculation engines capable of handling complex Scope 1, 2, and 3 emissions across multiple facilities and product lines. Software solutions must support various calculation methodologies, including the Greenhouse Gas Protocol, and provide capabilities for scenario modeling and target setting.
- Regulatory Compliance and Reporting: Software platforms must provide built-in compliance frameworks for CSRD and ESRS requirements, including automated report generation, digital tagging capabilities, and audit trail functionality. This includes support for double materiality assessments and the ability to generate reports in the required ESEF format [1, 5, 8, 17, 40, 41].

One of the most significant challenges facing manufacturing companies in implementing ESG software solutions is the complexity of integrating these systems with existing operational infrastructure. Manufacturing companies typically operate diverse technology ecosystems that have evolved over many years, including legacy systems that may not have been designed with data integration in mind. The integration challenge is compounded by the need to maintain operational continuity during implementation. Manufacturing companies cannot afford system downtime or disruptions to production processes, requiring careful planning and phased implementation approaches. The technical complexity of integration often requires specialised expertise that may not be available internally, necessitating partnerships with system integrators or software vendors [42].

Manufacturing companies face significant challenges in ensuring the quality and standardisation of data required for CSR reporting. Sustainability data is often collected from multiple sources using different methodologies and standards, creating inconsistencies that must be resolved before the data can be used for regulatory reporting [22]. The challenge is particularly acute for supply chain data, where manufacturing companies must rely on information provided by suppliers who may have varying levels of sophistication in data collection and reporting. Ensuring data quality across complex, multi-tier supply chains requires the development of standardised data collection protocols, supplier training programs, and verification mechanisms.

The implementation of comprehensive ESG software solutions requires significant financial investment and human resources. Initial costs include software licensing, system integration, data migration, and training, while ongoing costs encompass maintenance, updates, and continuous improvement activities. For many manufacturing companies, particularly small and medium-sized

enterprises, the cost of implementing sophisticated ESG software solutions may be prohibitive. This creates a potential competitive disadvantage for smaller companies that may struggle to meet CSRD requirements without adequate technological support. The challenge is compounded by the need for specialised personnel to manage and operate these systems effectively.

The ESG software market is characterised by significant fragmentation, with vendors ranging from established enterprise software companies like IBM and SAP to specialised sustainability software providers and emerging startups. This diversity creates both opportunities and challenges for manufacturing companies. While the variety of options allows for more tailored solutions, it also makes comparative evaluation extremely difficult, as vendors often use different terminologies, methodologies, and feature sets that are not easily comparable.

Manufacturing companies must navigate between different types of solutions, including point solutions that address specific aspects of ESG reporting (such as carbon accounting or supplier assessment), integrated platforms that provide comprehensive ESG management capabilities, and industry-specific solutions designed for particular manufacturing sectors. The challenge is determining which approach best fits the company\'s current needs while providing flexibility for future expansion [40].

METHODOLOGY

The aim of the study was to conduct a comparative analysis of selected IT tools supporting the reporting and management of ESG indicators and to develop practical recommendations for manufacturing companies with a diverse operational profile and scale of operations. Eight popular and widely used ESG tools on the global market were selected for the study, taking into account their recognition, availability for manufacturing companies, presence in industry rankings [43], availability of documentation and public sources of information. The following systems were included in the analysis: SmartHead, Diaphane, IBM Envizi, Envirly, Greenomy, APlanet, Velma ESG, PWC ESG Management Solution.

A set of 13 comparative criteria was developed for the study (see Table 2). The selection of criteria was based on the requirements of non-financial reporting standards, as well as observations of practical challenges in implementing ESG tools in companies of various sizes and industries. As the volume of data and the complexity of reporting standards increase, the importance of artificial intelligence features that can support users in automating reporting, identifying gaps, assigning indicators, and performing predictive analysis grows. Considering the AI capabilities criterion allows for the assessment of the modernity and innovation of a solution. In addition, functional aspects (e.g., standards compliance, scalability, processing and analysis of structured and unstructured types of data), technical aspects (e.g., integrations), and usability aspects (e.g., language accessibility, digital accessibility) were considered.

The analysis was based on triangulation of data from official websites of software manufacturers (documentation, price lists, product cards, roadmaps) and market reviews [44]. All information was collected in the period: May-June 2025 and concerned the current versions of commercially available software. In the absence of detailed information, the solution was classified as not offering a given functionality (which does not exclude its presence in custom offerings or for corporate clients).

Table 2
Comparison criteria

Criterion	Description
1. ESG Functionality Scope	Does the tool cover all ESG aspects – environmental (e.g., CO_2 emissions, energy consumption), social, and governance?
2. Solution Scalability	Can the system be scaled – is it suitable for both small companies and large corporations?
3. GHG Emissions Handling (Scope 1, 2, 3)	Does the tool allow reporting and analysis of direct, indirect, and supply chain emissions?
4. Supply Chain Tracking Capability	Does the software enable mapping and risk assessment of ESG throughout the entire supply chain?
5. Number of Language Versions	Which languages are available – important for international companies and multilingual employees?
6. Digital Accessibility (WCAG)	Does the user interface meet WCAG accessibility standards (e.g., WCAG 2.1 AA)?
7. Interface Intuitiveness & Data Tagging	Does the system allow easy tagging of ESG data to support automation of reporting and analysis?
8. Disclosure of Standard Implementation Cost	Does the software provider publish example implementation costs (e.g., for companies with 50, 250, and 1000+ employees)?
9. Licensing Cost	Are subscription models, one-time fees, or hidden costs (e.g., for APIs, support) available?
10. Readiness for Standards Reporting	Does the tool support reporting standards (e.g., GRI, ESRS, TCFD, CDP, SFDR)?
11. ERP/CRM Integration Capability	Is integration possible with SAP, Oracle, Salesforce, etc.?
12. Structured and Unstructured Data Types	Can the system handle both structured (e.g., numeric KPIs) and unstructured data (e.g., policies, narratives)?
13. AI Capabilities	Does the tool offer AI-based functions, e.g. predictive analytics, anomaly detection, or natural language generation?

The comparison was conducted using a qualitative, descriptive approach without applying numerical scoring or weighting of criteria. Each software supporting ESG reporting was assessed based on publicly available information across 13 predefined categories, with differences reflected through narrative descriptors rather than a quantitative evaluation framework.

Based on the results, the recommendations were developed taking into account the balance between functionality, implementation costs, and the level of technical advancement and availability. Additionally, the specific requirements of manufacturing companies were taken into account in the context of compliance with EU regulations (CSRD, ESRS) and international reporting frameworks (GRI, CDP, TCFD).

RESULTS

This study analysed eight selected IT tools supporting ESG (Environmental, Social, Governance) reporting and management, with particular emphasis on the needs of manufacturing companies. The comparison was based on 13 criteria, including the scope of support for greenhouse gas (GHG) emission reporting, the ability to track risks in the supply chain, compliance with regulations (e.g. ESRS, GRI), integration with ERP/CRM systems, availability of language versions and the AI capabilities (see Table 3).

Most of the tools analysed cover a wide range of ESG functions, with full integration of environmental, social and governance aspects provided by IBM Envizi, Greenomy and PwC ESG Management Solution, among others. These tools are also best suited for reporting GHG emissions in Scope 1, 2 and 3. IBM Envizi in particular stands out with its advanced emission modeling functions and analyses based on actual and estimated data. Envirly and Velma ESG, on the other hand, focus mainly on environmental aspects, making them suitable for companies focusing on decarbonization, although with less support for social and governance aspects.

In terms of scalability, IBM Envizi and PwC ESG Management Solution appear to be the most suitable for implementation in extensive corporate structures, based on their stated capabilities and target user base. These tools offer flexible implementation models, the possibility of configuration for the specifics of the industry and integration with systems such as SAP, Oracle or Salesforce. On the other hand, SmartHead, Velma ESG and Envirly present a simplified and intuitive model, tailored to the needs of small and medium-sized companies that are just starting the process of collecting ESG data and reporting. The functionality enabling the assessment of ESG risks in the supply chain has been fully ensured only in the case of IBM Envizi and PwC ESG Management Solution, which enable monitoring and assessment of suppliers, risk assignment and creation of Scope 3 data mapping. It is worth noting that Diaphane also offers extensive tools for analysing data in the supply chain, although integration with ERP systems often requires additional implementation.

In terms of digital accessibility compliance with the WCAG 2.1 (AA) standard, most solutions – including APlanet, Velma ESG, and SmartHead declare that the interface is adapted to the needs of people with disabilities, which is an important aspect of compliance with EU regulations on digital accessibility.

When it comes to cost transparency, only a few vendors, notably Envirly and Velma ESG, provide sample implementation calculations for companies of varying scale. Other solutions operate in a project model or require individual pricing, which can be a barrier for smaller organisations. Among the analysed tools, the most comprehensive support for ESG reporting standards, such as GRI, ESRS, SFDR, CDP, and TCFD, is offered by IBM Envizi, Greenomy, and APlanet. IBM Envizi provides automated alignment of ESG data with various reporting frameworks, facilitating efficient and standardised disclosures. Greenomy is strongly focused on compliance with EU regulations, particularly the EU Taxonomy and ESRS, making it especially suitable for organisations operating within the European regulatory environment. APlanet, in turn, supports multiple reporting structures with a strong emphasis on alignment with GRI and TCFD, offering flexibility for companies reporting under diverse frameworks.

The structured and unstructured data types criterion was used to assess whether a software solution is capable of managing both structured (quantitative) data, such as emission indicators, and unstructured (qualitative) data, such as policies, procedures, and narrative disclosures. Among the tools evaluated, IBM Envizi, PwC ESG Management Solution, and Greenomy provide the most robust support for both data types, in line with ESRS requirements that involve 1100-1200 datapoints – of which only 300-400 are numerical. By contrast, tools such as SmartHead and Velma ESG focus primarily on structured indicators and offer limited capacity for managing textual ESG documentation.

The AI capabilities criterion reflects the growing relevance of artificial intelligence in supporting ESG reporting. The results reveal that only IBM Envizi and PwC ESG Management Solution currently offer advanced AI-based functionalities, including automated tagging, anomaly detection, and predictive modelling. Tools such as Greenomy and APlanet also exhibit medium-level AI features, particularly in natural language processing and automated standard alignment. Meanwhile, SmartHead and Velma ESG do not currently incorporate AI functionality. This finding confirms a generally low market maturity in AI integration, despite its high potential as highlighted in recent literature.

Table 3
Comparison of selected tools supporting ESG reporting

	Tool	ESG Scope	Scalability	GHG Scope 1-3	Supply Chain	Lang Versions	WCAG	Tagging/ UX	Implementation Cost	License Model	Reporting Standards	ERP/CRM Integration	Type of data	AI features
1	SmartHead	Comprehensive ESG: environment + social + governance, GRI-certified	Small–large companies	Yes (estimated) – no details	No data	No data	No data	Documentation + UX portal	Demo, no public pricing	SaaS (cloud)	GRI	No data	Limited ability to add narratives and policy documents	No AI components
2	Diaphane	ESG + carbon footprint, user roles	Small–large companies	Yes, footprint (GHG Protocol)	Role management (possibly suppliers)	No data	No data	Roles, UX dashboards	Demo, no public pricing	SaaS	GRI, ESRS, GHG Protocol	No data	Ability to report indicators and attach narratives, but lacks full integration	Support for semantic matching of indicators
3	IBM Envizi	Comprehensive ESG + workflow, decarbonization	Small–corporations	Yes	Yes	Min. 7 languages	No data	Advanced tagging, dashboards	Price calculator	Modular subscription	GRI, CDP, TCFD, ESRS	API, ERP	Advanced support for quantitative and qualitative data in the ESRS context	Prediction, ESG data classification
4	Envirly	ESG + LCA, CBAM, CSRD, ESRS	SME–corporations	Yes, Scope 1-3	Supplier forms	No data	No data	External forms, advanced UX	Packages (pricing upon request)	Subscription + packages	CSRD, ESRS, GRI, CBAM, GHG Protocol	GS1 integration, API	Non-numeric data can be added but is not centrally analyzed	Basic predictive analytics
5	Greenomy	ESG, AI-powered, CSRD, EU Taxonomy	SME–large companies	Yes	No data	No data	No data	Automat., simple UX	Demo, no pricing	SaaS	CSRD, EU Taxonomy, ISSB	API integrations	Supports the ESRS framework, including policies and narratives	NLP for narrative text processing
6	APlanet	ESG, KPI analytics	SME–large	Yes	No data	No data	No data	Automat. data collection	No pricing, on request	SaaS	ESG standards (not specified)	No data	Ability to manage ESG documentation and metadata	Automatic assignment of indicators to standards
7	Velma ESG	ESG + decarbonization GRI, ESRS	SME–corporations	Yes (GHG Scope)	No data	No data	No data	Forms, UX workshops	Packages available	Subscription + training	GRI, ESRS, GHG Protocol, CRREM	No data	Integration with corporate documentation, but primarily focused on numerical data	No AI components
8	PwC ESG Management	ESG data, KPI, CO₂, CSRD, ESRS	SME–corporations	Yes, Carbon footprint	Supply chain (optional)	No data	No data	Corporate UX dashboards	No pricing, on request	SaaS + consulting	CSRD, ESRS, GRI	SAP Datasphere, SCT, API	Supports the full spectrum of data required by ESRS	Advanced AI supporting compliance, NLP

Source: based on [45, 46, 47, 48, 49, 50, 51, 52].

Recommendations for ESG Software Selection

Based on the comparative analysis of selected ESG software tools, a set of practical recommendations has been developed to guide manufacturing companies in selecting appropriate solutions. The recommendations consider company size as well as strategic priorities such as decarbonization, supply chain complexity and regulatory compliance (see Figure 2).
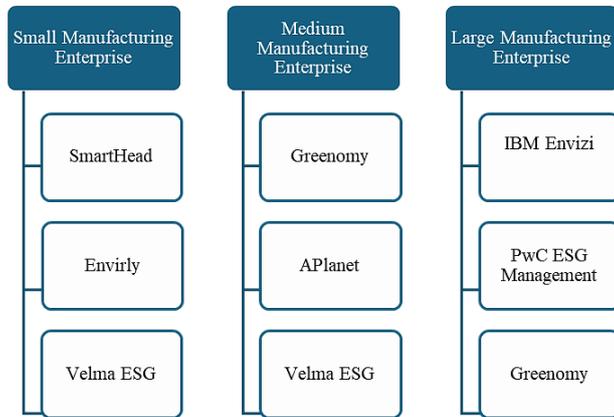

Fig. 2 ESG software recommendations by company size

For small manufacturing enterprises, the most critical selection criteria include low entry cost, ease of implementation, intuitive user experience, and access to basic ESG reporting functionalities. In this context, three tools are particularly well-suited. SmartHead provides an accessible, quick-to-deploy platform with core environmental and social reporting functions, making it ideal for companies without a dedicated ESG department. Envirly offers a cost-effective solution with GHG Protocol and ESRS compliance, allowing companies to begin monitoring and reporting their emissions. Velma ESG combines user-friendly design with features supporting data categorization and simple report generation, making it a strong option for small and medium-sized enterprises (SMEs).

Medium-sized manufacturing enterprises require scalable solutions aligned with EU regulations (e.g., ESRS), and at least basic integration capabilities with ERP or CRM systems. Recommended tools for this category include Greenomy, APlanet, and Velma ESG. Greenomy delivers high regulatory compliance (including ESRS and SFDR) and supports integration with corporate IT infrastructures. APlanet offers a broad ESG feature set, including social aspects, and is distinguished by robust analytics and multilingual support, which is advantageous for cross-border operations. Velma ESG continues to be a suitable choice for growing SMEs, enabling the internal development of ESG competencies and progressive functional expansion.

Large manufacturing enterprises and corporations prioritize comprehensive ESG reporting (Scopes 1-3), automation, full integration with systems such as SAP, Oracle, or Salesforce, and compliance with multiple reporting frameworks. In this segment, IBM Envizi, PwC ESG Management Solution, and Greenomy are the most robust options. IBM Envizi is a highly automated, enterprise-grade platform offering full compliance with GRI, CDP, TCFD, and SFDR, and advanced integration capabilities. PwC ESG

Management Solution provides a flexible, project-based deployment model tailored to the needs of complex organisations and sector-specific requirements. Greenomy also demonstrates a strong regulatory orientation and solid data architecture suitable for managing ESG data across large, multi-entity structures.

Taking into consideration the strategic priorities, recommendations for software selection were also developed (see Figure 3).
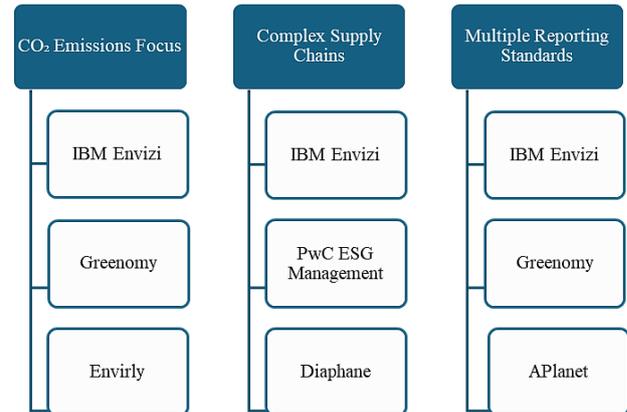

Fig. 3 ESG software recommendations by strategic priorities

Companies prioritising CO_2 emissions reduction should focus on full GHG tracking across Scopes 1, 2, and 3, automated emissions calculations, and compliance with GHG Protocol and ESRS E1. Recommended tools in this area are IBM Envizi, Greenomy, and Envirly. IBM Envizi offers advanced automation and precise emissions tracking. Greenomy is specifically designed to meet EU climate reporting requirements. Envirly serves as a practical, user-friendly solution for organisations beginning their decarbonization journey.

When addressing ESG risks in complex supply chains, the most important features include supplier mapping, ESG risk assessment across the value chain, and Scope 3 data management. Recommended tools for these requirements include IBM Envizi, PwC ESG Management Solution, and Diaphane. IBM Envizi supports advanced supplier data tracking and comprehensive ESG risk management. PwC ESG Management Solution enables holistic supply chain analysis and audit functionalities. Diaphane specialises in data analysis and ESG evaluation within extensive supplier networks, offering valuable capabilities for organisations aiming to implement sustainable procurement strategies.

To support broad ESG reporting compliance, companies should seek tools aligned with standards such as GRI, ESRS, SFDR, CDP, and TCFD. Recommended tools include IBM Envizi, Greenomy, and APlanet. IBM Envizi offers automated data alignment with multiple frameworks, making it ideal for streamlining standardised disclosures. Greenomy is particularly well-suited for companies operating in the EU due to its strong focus on EU Taxonomy and ESRS compliance. APlanet provides versatile reporting capabilities with an emphasis on GRI and TCFD, supporting organisations that require flexibility across various ESG frameworks.

DISCUSSION AND CONCLUSIONS

The comparative analysis of eight ESG software solutions reveals heterogeneity in functionality and regulatory compliance capabilities, reflecting the rapidly evolving sustainability reporting landscape under the Corporate Sustainability Reporting Directive (CSRD). Čufar and Belak [1] findings reveal that NFRD and CSRD implications create varying organizational requirements, confirming our identification of distinct tool categories for different enterprise sizes. This diversity suggests the market is responding to differentiated manufacturing sector needs, from small enterprises beginning sustainability journeys to large corporations requiring sophisticated supply chain monitoring. The integration of artificial intelligence emerges as a critical enabler for effective ESG reporting. Chen [34] findings reveal that AI integration significantly improves ESG reporting quality, yet our analysis indicates limited AI-enhanced features across most tools, suggesting market immaturity. Rane et al.'s [30] findings indicate that AI-driven approaches can enhance the implementation of ESG criteria, while Correia and Água's findings suggest that AI paradigms improve corporate transparency [35]. The functionality of IBM Envizi in emission modeling reflects its AI-driven features enabling automated framework alignment, yet organizations investing in AI-enabled platforms appear better positioned for CSRD compliance. Regarding regulatory compliance, the analysis shows varying support for different reporting standards, reflecting the complex landscape described by Moya [26], whose findings reveal that sustainability reporting regulation continues to evolve. IBM Envizi, Greenomy, and APlanet offer the most comprehensive multi-framework support, crucial for global manufacturing operations.

In addition to AI capabilities, the ability of ESG software tools to handle both structured and unstructured data has emerged as a critical success factor for CSRD compliance. The European Sustainability Reporting Standards (ESRS) require the disclosure of approximately 1100-1200 data points, of which only about 300-400 are quantitative indicators, while the remainder consists of qualitative disclosures such as policies, governance processes, sustainability targets, and narrative explanations [5, 13]. This dual nature of data requires ESG systems not only to aggregate numerical performance indicators but also to manage and contextualise unstructured, often document-based inputs. However, the findings indicate that only a subset of tools - primarily IBM Envizi, PwC ESG Management Solution, and Greenomy - offer mature functionality for managing both types of data effectively, confirming the challenge noted by Novicka and Volkova [10] regarding the digitalisation of non-financial disclosures. Furthermore, the analysis underscores the transformative potential of AI in automating ESG data collection, classification, and standard alignment. Although the overall market maturity in this area remains limited, several tools are beginning to integrate natural language processing (NLP), predictive analytics, and automated tagging mechanisms [20, 31, 32]. These technologies can enhance the consistency and depth of sustainability reporting by reducing manual workload, increasing data reliability, and enabling dynamic alignment with evolving disclosure frameworks. The observed gap between AI's theoretical benefits and its limited current implementation supports the call for further development in this area, especially within the manufacturing context where data heterogeneity and operational complexity are high [13, 34].

The research reveals clear market segmentation based on organisational complexity, supporting Baumgartner and Ebner [16] findings that reveal corporate sustainability strategies require different maturity levels. Small enterprises require low-barrier-to-entry solutions like SmartHead, Envirly, and Velma ESG offering simplified interfaces and cost-effective models. Medium-sized enterprises need scalable solutions with EU regulatory alignment, while large enterprises require comprehensive platforms capable of handling multi-entity structures and extensive integration requirements. This segmentation reflects varying sustainability reporting maturity levels across manufacturing companies.

The findings confirm that no single tool universally meets all compliance needs. However, careful selection based on a company's size, ESG maturity level, sector-specific requirements, and internal resources can significantly enhance both the efficiency of the reporting process and the quality of disclosed information. These results underline the importance of aligning software functionality not only with regulatory expectations but also with organisational capacity and strategic ESG objectives.

The research contributes to the growing body of literature on digital transformation in sustainability reporting and provides practical guidance for manufacturing companies navigating the complex ESG software selection process. As the CSRD implementation progresses and ESG software capabilities continue to evolve, ongoing research and market assessment will be essential for maintaining effective sustainability reporting practices in the manufacturing sector.

Limitations

The study has some limitations. Some ESG software vendors do not publicly disclose complete information about implementation costs, development roadmaps, or detailed integration architecture. In such cases, it was necessary to rely on secondary data (e.g., consulting reports, user reviews), which may not fully reflect the actual situation. The assessment of certain criteria was based on qualitative sources, which may lead to interpretative differences. The lack of user testing in a real environment may limit the reliability of these evaluations. The analysis was conducted during May and June 2025. The ESG Tech market is highly dynamic, with vendors regularly releasing new versions, features, and changing pricing models. Therefore, the results should be interpreted as a snapshot of the market at a specific point in time.

Future directions

The results of this analysis provide a foundation for further in-depth research, particularly in the context of the

application of ESG tools in the manufacturing industry. It is advisable to conduct case studies of ESG tool implementations in manufacturing companies. This would allow for an evaluation of the actual effectiveness of the tools, implementation challenges, and their impact on decision-making processes and non-financial reporting. It is also recommended to conduct user-centred research involving end users (ESG managers, analysts, compliance officers) to assess the intuitiveness, accessibility (including WCAG compliance), training time, and integration into daily processes.

In addition, future research could focus on a more detailed identification of material ESG topic clusters relevant for the manufacturing sector – such as environmental domains E1 (Climate Change), E2 (Pollution), E5 (Circular Economy), and social domain S1 (Labour Conditions) – would allow for deeper alignment of software assessment with sector-specific needs. Given the evolving nature of the ESRS framework and ongoing updates in sector-specific guidance, future work should address regulatory uncertainty and monitor how software providers adapt to the changing compliance landscape.

Finally, future analyses should explicitly differentiate between the functional and implementation needs of SMEs and large corporations, acknowledging their different levels of ESG reporting maturity, resources, and regulatory obligations.

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