Sustainability reporting in the digital age:

Overcoming challenges for SMEs and EMDEs

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Executive Summary

This paper addresses the challenges faced by Small and Medium Enterprises (SMEs) and Emerging Markets and Developing Economies (EMDEs) in meeting the growing demand for sustainability reporting. It proposes two main approaches to tackle these challenges: designing proportionate reporting standards for SMEs and EMDEs and leveraging digital technologies.

We also posit two preliminary hypotheses regarding how digital tools can support SMEs and EMDEs in implementing sustainability reporting. First, technology can reduce the cost of generating information, making reports more accessible to smaller companies and emerging markets. Second, technology can enhance the value of the produced sustainability data, thereby increasing the value and utility of reports for these entities.

The paper concludes by focusing on five key recommendations for jurisdictions and standard-setting bodies: (a) Adopting streamlined and flexible standards for SMEs to ensure proportionality and avoid unnecessary costs; (b) Building capacity for SMEs in sustainability reporting, including international support for knowledge sharing; (c) Leveraging technology to reduce the cost for SMEs and EMDES in generating sustainability reporting data; (d) Leveraging technology to enhance the value of sustainability reporting data generated by SMEs and EMDEs; (e) Improving the sustainability reporting service ecosystem.

Editor's note

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1. Introduction

The field of sustainability reporting is undergoing significant changes as it is increasingly recognized as a key tool for promoting a transition to a more sustainable economy.

As momentum for sustainability disclosure grows, the regulatory landscape is rapidly evolving (Carrots & Sticks, 2020, 2023), and the field is entering a critical phase in which key features are being defined (Deloitte, 2024).

Notably, the debate has shifted from *whether* to disclose sustainability matters to *how* such disclosures should be made. Furthermore, the scope of regulatory measures is expanding, both geographically to include Emerging Markets and Developing Economies (EMDEs) and across business categories to impact smaller enterprises (commonly referred to as SMEs). These expansions are driven by the institutional developments of disclosure frameworks and standards aimed at overcoming the numerous challenges related to standardisation and comparability of data, as well as interoperability between different tools.

Both the International Sustainability Standards Board (ISSB) and the European Corporate Sustainability Reporting Directive (CSRD) exemplify the current dynamics in sustainability reporting. As a product of convergence between many different sustainability reporting institutions, the ISSB was established to develop a universal set of sustainability reporting standards – consolidating the "alphabet soup" of voluntary initiatives into "a truly global baseline of disclosure". Meanwhile, as part of the European Green Deal package, the CSRD has significantly expanded the scope of previous legislation on non-financial reporting in the EU, triggering the development of the European Sustainability Reporting Standards (ESRS) that will guide the disclosures of over 50.000 companies.

Two trends become visible from these cases.

First, the push for globalising sustainability reporting, illustrated by the international consensus around the ISSB Standards, which have been endorsed by the International Organization of Securities Commissions (IOSCO), the Financial Stability Board, the G20 and the G7 Leaders.

Second is the increasing focus on data requirements related to the reporting entity's supply chain, thereby extending the demand to numerous enterprises.

These trends explain the geographic and categorical expansions in the scope of sustainability reporting practices, raising significant issues.

One of the anticipated challenges concerns the higher compliance burdens likely to be encountered by EMDEs and SMEs (Financial Stability Board, 2023), potentially leading to negative impacts in the regulatory arena. Indeed, during the public consultation process of the ISSB Standards, concerns were raised about the impact on firms in jurisdictions needing more time to prepare, including SMEs. Specifically, contributions pointed to "the risk of inaccurate emission statements due to inadequate reporting infrastructures, which could have the unintended consequences of driving capital flows away from the countries that need them most" (ISAR, 2022, p. 3).

Addressing such concerns will involve ensuring proportionality in reporting requirements according to each company's size and establishing appropriate transition periods. This acknowledges that reporting mandates will have varying impacts on different entities. To add in complexity, the sustainability transition challenges are compounded by those of the digital transition (European Commission, 2022), which will also have differentiated impacts, presenting both opportunities and risks depending on a given entity's readiness to adapt to the coming transformations.

Digital technologies play a pivotal role in fostering innovation in sustainability reporting, especially for SMEs and EMDEs. These technologies, encompassing both digitalization (the conversion of information into a digital format) and digital transformation (the integration of digital technology into all areas of a business, fundamentally changing how it operates and delivers value to customers), offer numerous benefits, as well as risks.

This study focuses on the specific challenges faced by SMEs in responding to the growing demand for sustainability reporting and the related digital technologies that may serve as tools to meet these challenges. To some extent, the reflections can be extrapolated to EMDEs, which, however, also present unique peculiarities and face specific challenges in the evolving scenario described above.

The report proposes two main approaches to address the sustainable reporting challenges faced by SMEs and EMDEs: designing proportionate reporting standards and leveraging digital technologies.

When addressing proportionate reporting, we suggest topics such as standards that ensure proportionality and avoid unnecessary costs, including a "building block approach"; and the need for public consultations to design better standards for SMEs and EMDEs.

We also posit two preliminary hypotheses regarding how digital tools can support SMEs and EMDEs in implementing sustainability reporting. First, technology can reduce the cost of generating information, making reports more accessible to smaller companies and emerging markets. Second, technology can enhance the value of the produced sustainability data, thereby increasing the value and utility of reports for these entities.

In other words, if the cost of producing good sustainability reporting is minimal, and if the value of these reports is worth its weight in gold, technology can provide strong incentives for making sustainability reporting more equitable and accurate.

The paper was developed through the dialogue between two sets of specialists. Viviane Muller Prado and Gabriela de Oliveira Junqueira focused on the legal and regulatory environment of sustainability reporting, providing the broader context for discussing the role of SMEs in the theme (Section 1). Conversely, and looking at the described context, Fabro Steibel examined the sustainability reporting solutions related to digitalization (Section 2) and the opportunities for more radical digital transformation (Section 3).

This multidisciplinary exchange of ideas was coordinated by the Climate and Society Institute, aiming to promote broader reflections on the risks and potentialities within the expanding scope of sustainability reporting. The recommendations presented in Section 4 summarize this joint effort, which we hope will support the Sustainable Finance Working Group (SFWG) at the G20.

As a final note, we clarify the use of terminologies that might be interpreted differently based on the readers' background. Specifically, we highlight the uses of the terms "taxonomy" and "standards" (Timmermans; Epstein, 2010). In our work, standards refer to a collection of rules and procedures that guide the development of sustainability

reporting. In the fields of sustainable finance and sustainability reporting, taxonomy refers to a classification system for defining activities aligned with a net-zero path[1], while a standard means a defined set of rules that prescribe what and how information on sustainability topics should be disclosed.

In digital reporting, these terms have different meanings. “Taxonomy” refers to a form of “digital taxonomy”, i.e., a domain-specific dictionary used in reporting, that defines specific concepts, their attributes, rich metadata, and their interrelationships (Wagenhofer, 2024).

Methodology note: this paper benefited from the contributions of nine experts in the field, whose suggestions have been incorporated in the final manuscript.

[1] Available at: https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en

2. Expanding the scope of sustainability reporting

In what follows, this section details the institutional context in which sustainability reporting extends to SMEs and, to some extent, EMDEs in general. As we attempt to demonstrate, to understand this environment correctly, it is crucial to distinguish between the direct and indirect obligations created by new regulations, as well as comprehend the strategies and tools that help overcome specific challenges.

2.1. Direct and indirect sustainability reporting requirements

Through the waves of sustainability reporting, the emergence of legal obligations to disclose sustainability data has interacted with voluntary initiatives (Spiesshofer, 2018), driving institutional development in the field (Monciardini; Mähonen; Tsagas, 2020). Recent regulatory endeavours such as the EU Taxonomy, the CSRD, and the Sustainable Finance Disclosure Regulation (SFDR) have imposed direct sustainability reporting mandates primarily focusing on large and publicly traded corporations through financial and securities regulation (Eurochambres; SMEunited, 2023).

Notably, these initiatives stem from and promote changes in the information demands of investors and financial regulators, who increasingly view issues such as climate change through the lenses of financial risks and opportunities (UNEP Finance Initiative, 2019; Bolton et al., 2020). Growing investor demand for data has fuelled calls for greater harmonisation and reduced complexity in sustainability reporting (Adams; Abhayawansa, 2022). In alignment with this context, the global baseline provided by the ISSB Standards are "investor-focused" (de Villiers; La Torra; Molinari, 2022), i.e., "designed to meet the needs of existing and potential investors, lenders and other creditors".[2]

The notable exception to the general focus on large corporations in legal disclosure mandates is the inclusion of listed SMEs within the scope of the CSRD.

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2. IFRS. ***Introduction to ISSB and IFRS Sustainability Disclosure Standards***. Available at: https://www.ifrs.org/sustainability/knowledge-hub/introduction-to-issb-and-ifrs-sustainability-disclosure-standards/

From 2026 onwards, the new European Directive will extend sustainability reporting requirements to SMEs that are listed on regulated European markets that meet at least two of the following criteria: (i) a balance sheet total of EUR 5 million or above; (ii) a net turnover of EUR 10 million or above; and (iii) an average of 50 or more employees during the financial year.[3] As detailed below, listed SMEs' obligations will, however, be guided by a specific standard that derogates the application of ESRS in line with the principle of proportionality.

In any case, even if not within the direct scope of most regulatory measures, SMEs in general are already feeling the pressure of the increasing prevalence and sophistication of sustainability reporting (Shields; Shelleman, 2017) as they are frequently asked for information by "customers, banks, investors or other stakeholders" (European Commission, 2023). While from the legal point of view sustainability reporting may appear as optional for SMEs, "they may be forced to do so, in order to meet the reporting requirements of financial institutions and significant clients in their value chain" (European Commission, 2022, p. 81).

By employing concepts such as "indirect effect" (Allgeier; Feldmann, 2023), "spillover effect" (Huq et al., 2023) or even "trickle-down effect" (Eurochambres; SMEunited, 2023), different actors have attempted to highlight the impact of sustainability reporting mandates on SMEs, particularly due to requirements on supply-chain data and their roles as suppliers to large companies or their need to access credit through bank loans.

For example, the CSRD, for instance, Article 19a para. (2) point (f) (ii) states that among the disclosed information, it shall be included a description of "the principal actual or potential adverse impacts connected with the undertaking's own operations and with its value chain, including its products and services, its business relationships and its supply chain, actions taken to identify and monitor those impacts, and other adverse impacts which the undertaking is required to identify pursuant to other Union requirements on undertakings to conduct a due diligence process".

Alongside the emerging breed of due diligence laws, the new sustainability reporting mandates' focus on supply-chain data is driving the development

[3] Listed micro-enterprises are exempt from the scope of the CSRD.

of legislation aimed at governing “sustainable supply chains” (Sarfaty, 2015; LeBaron; Rühmkorf, 2017). Using the lead firm as a regulatory target, these “supply chain laws” constitute a new legal field that often have transnational effects (Salminen; Rajavuori, 2019) as it seeks to increase corporate accountability across supply chains (Schilling-Vacaflor, 2021). As documented, business leaders worldwide are reporting moderate to very high pressures to advance on supply chain sustainability (Correll; Betts, 2023).

Regarding financial institutions, their own obligations to assess and disclose the sustainability of their portfolios (e.g., in the EU, Regulation n. 2019/2088) are driving them to pass on reporting requirements to their clients, impacting many loan-dependent SMEs. As explained, “good ESG performance will be a prerequisite to access (more affordable) financing” (Leempoel, 2023), and this is becoming an important factor in understanding sustainability as a competitive advantage among SMEs.

Access to funding is particularly relevant, as sustainable finance requirements are increasingly adopted. Indeed, SMEs and EMDEs unable to fulfil data requirements may suffer the consequences of higher capital costs. EMDEs are vulnerable to these capacity gaps in data collection and non-financial disclosure, posing a significant bottleneck to investments needed for achieving the sustainable development goals (OECD, 2023).

In this context, where there is a high demand to collect data from SMEs within a company’s value chain or a financial institution’s portfolio, various mechanisms are used to request information to SMEs, including different supplier sustainability self-assessment questionnaires (Fraser; Müller; Schwarzkopf, 2020). **This can be overwhelming,** given that “[t]he process of sustainability data gathering can be extremely challenging and costly for SMEs, which often face limited financial, technical and human resources, due to the complexity of existing private reporting frameworks, involving a huge array of KPIs and competing requests from financial institutions, investors, large enterprises and other stakeholder in the supply chain” (European Commission, 2022, p. 81).

The observed expansion of scope for sustainability reporting with the inclusion of SMEs is indeed significant, considering their substantial share in economic affairs (Galli; Torelli; Caccialanza, 2023). However, there are considerable challenges that must be acknowledged, given the scarcity of resources that characterise many SMEs (Shields; Shelleman, 2017), and the fact that “much of the support and guidelines available for

sustainability reporting do not cater to the needs of SMEs" (CDP, 2021, p. 4).

2.2. Facing the challenges: simplified standards and new digital tools

Beyond efforts of capacity building as sustainability reporting expands its scope, the debates around the topic revolve around questions on how to ensure proportionality in the requirements.

The emerging avenues to tackle these challenges involve two interconnected dimensions: an intentional effort to simplify reporting standards tailored for SMEs and promoting the increased use of digital technologies to alleviate reporting burdens. For analytical purposes, we examine each dimension separately.

In the realm of developing "SME-proportionate standards", the Carbon Disclosure Project (CDP) framework for climate disclosures focused on SMEs offers an illustrative example, as it aimed "to strike a balance between comprehensive climate disclosure and reduced reporting burden" (CDP, 2021, p. 20). Recognizing the lack of reference, CDP's framework relied on a modular design that could be phased in over a three-year period, offering enough flexibility to SMEs in their reporting.

Another example of sensitivity to SME capacities in sustainability reporting is evident in the evolving implementation of the EU CSRD. The regulation not only mandates the development of specific standards for SMEs but also includes safeguards against excessive data demands within their value chains (in the form of a "cap" in data requests), stating that "[s]ustainability reporting standards shall not specify disclosures that would require undertakings to obtain information from small and medium-sized undertakings in their value chain that exceeds the information to be disclosed pursuant to the sustainability reporting standards for small and medium-sized undertakings" (CSRD, Article 29b, 4).

Regarding the specific SME standards, the CSRD acknowledges the resource limitations faced by SMEs, with its Recital 21 stating that listed SMEs and those outside the scope of the CSRD should be given the possibility of reporting according to proportionate standards, and Article 29c stipulating the development of SME-proportionate standards. The

European Commission has entrusted the development of these two additional standards to EFRAG.

One of the standards is dedicated to Listed SMES (LSME),[4] which fall under the scope of the CSRD and thus have a direct obligation to report. The other standard is dedicated to non-listed SMEs, which are outside the regulatory scope but face reporting demands within their value chains and credit relations and are encouraged to adopt the so-called Voluntary ESRS for SMES (VSME).[5] These standards complement the ESRS which was primarily tailored for large companies under the CSRD.

The exposure drafts of both LSME and VSME state that the standards establish sustainability reporting requirements for SMEs "that are proportionate and relevant to their capacities and characteristics and to the scale and complexity of their activities" (EFRAG, 2024a, p. 9). They are "based upon the key concept of proportionality" and therefore consider SME's "fundamental characteristics" (EFRAG, 2024b, p. 5).

The LSME draft results from an extensive simplification effort departing from the ESRS, which significantly reduced the data points required for undertakings under its scope (i.e., listed SMEs). Beyond eliminating some reporting requirements, the LSME made others voluntary. Unlike the ESRS, all sections in the LSME are sector-agnostic, "meaning that they apply to all undertakings regardless of the sector or sectors they operate in" (EFRAG, 2024a, p. 10).

The VSME draft, in turn, was developed as a standalone document based on other ESG questionnaires applied to SMEs but following a conceptual coherence with the ESRS. Its primary objectives are to support SMEs in (a) contributing to a more sustainable and inclusive economy; (b) improving the management of the sustainability issues they face; (c) providing information to satisfy data demands from lenders/credit providers and investors; and (d) providing information that will help satisfy the data demand needs of large undertakings requesting sustainability information from their suppliers (EFRAG, 2024b).

The VSME utilizes simplified language and comprises three modules that can be used for preparing sustainability reports: the basic module; the

[4] For an overview of the draft, refer to <https://www.greenomy.io/blog/simplified-esrs-smes-under-csrd-what-you-need-to-know>.
[5] For an overview of the draft, refer to <https://www.greenomy.io/blog/non-listed-sme-reporting-guide-vsme-esrs>.

narrative module covering policies, actions, and targets; and the business partners module. The latter, known as “Business Partner Module”, outlines data points to be reported that are likely to be included in data requests from lenders, investors, and corporate clients. By resorting to this module, the VSME aims to replace the excessive number of questionnaires currently used in the market that channel uncoordinated data requests to SMEs, and this is why it is described as “a much needed protection for SMEs from ad-hoc-requests by large companies, which are expected to rise significantly due to the extensive supply-chain-reporting required by the CSRD” (Allgeier; Feldmann, 2023).

Within the ISSB arena, there has been a call for a SME-proportionate standard, often referred to as “ISSB for SMEs” (ISAR, 2022, 3). In this sense, representatives from sectors such as the insurance industry encouraged the ISSB to “consider further action to take account of the distinct needs of users of smaller non-listed entity disclosures and the cost to these entities of full ISSB disclosure” (Saporta; Walker, 2023, p. 2–3).

Current perspectives, however, suggest that the released ISSB standards already offer enough flexibility to allow for tailored data points, assessing the materiality where relevant. Instead of developing new specific standards, this stance focuses on capacity building for SMEs and EMDEs as these standards are globally adopted.

Other initiatives to find a common ground among companies not directly subject to legal reporting obligations are exemplified by the ESG Integrated Disclosure Project (ESG IDP), spearheaded by lenders to enhance transparency by borrowers in private credit and syndicated loan transactions. The ESG IDP Template is a reporting tool “that represents a proportionate set of questions that are designed to solicit a global baseline of information from private companies”. As explained in their overview, the ISG IDP followed three guidelines in building their disclosure template, namely proportionality, credit-materiality, and harmonisation (ESG IDP, [n.d.]).

In alignment with the simplification efforts, various initiatives are dedicated to leveraging digital technologies to alleviate resource constraints among SMEs. Digital tools are revolutionising sustainability reporting, as evidenced, for example, by discussions on digital taxonomies to standardize tagging rules within both ESRS (EFRAG, 2024c) and ISSB frameworks (IFRS Foundation, 2023). These transformations hold

particular significance for SME reporting requirements, as discussed above.

For instance, the alliance of “Bankers for Net Zero” and Icebreaker One are developing Project Perseus, which aims to automate GHG emissions reporting for SMEs in the UK. In Brazil, the Ethos Institute, in collaboration with SEBRAE, has developed simplified reporting standards for micro and small enterprises. These standards are accessible through an online platform that is freely available and simplifies data collection. Similarly, the Impact Scoring Platform (ISP), a joint effort by Finance&Invest.Brussels and Greenomy, aims to streamline ESG reporting for SMEs.

Most notably, GRI, the most used sustainability reporting standard among the world’s largest companies (de Villiers; La Torra; Molinari, 2022) “is currently developing a new SME reporting tool that will enable multinationals to directly engage their supply chains in the reporting process”. Described as an “innovative and unique reporting tool”, the GRI online platform is being developed within the Corporate Sustainability and Reporting for Competitive Business program. As portrayed in one of its reports, “[t]he implementation of the program in Peru has taken sustainability reporting from a niche practice among big companies to a critical and essential one adopted by companies of different sizes and sectors around the country” (Global Reporting Initiative, 2021).

Overall, the above assessment of the landscape of sustainability reporting reveals the pressures on SMEs to report on sustainability matters, driven by their value chains and credit relationships, even when not legally obligated. As we argue, this brief investigation offers important insights into upcoming challenges and the potential of digital tools to address them. These insights can be summarised into four main points:

- The need to ensure proportionality in the applicable standards to SMEs through reduced and flexible reporting requirements, prepared in a simplified manner.
- Avoiding unnecessary costs that could undermine sustainability as a competitive advantage.
- Promoting capacity building among SMEs for sustainability reporting.
- A promising mechanism could be to ensure appropriate transition periods combined with a modular approach to standards.

3. The role of digitalization

To support the Sustainable Finance Working Group (SFWG) in providing a set of recommendations to address sustainability reporting challenges for SMEs and EMDEs, we now examine existing digital tools that can enhance the value of sustainability reporting. This is crucial considering that the anticipated widespread adoption of digital technologies in the near future, which will have disruptive impacts on financial and sustainable markets (Pizzi et al, 2023).

The central thesis of this section posits that the sustainability reporting can enhance its value by integrating various digital . This integration can either reduce the costs associated with generating sustainability data or increase its value.

For example, in the case of the "Ethos-Sebrae Indicators for sustainable and responsible business" initiative mentioned earlier, the use of digital tools has not only increased the accessibility of sustainability reporting but also contributed to lowering management costs. Nevertheless, the potential value of these indicators could be further enhanced through the adoption of a broader array of digital solutions.

If these indicators were presented in open formats (in addition to the existing textual PDFs), inputted data could be reused by other software solutions or cloud digital repositories. Similarly, providing data with clear metadata information and simple Application Programming Interfaces (APIs) would significantly improve the interoperability of the information provided.

3.1. The digitalization of sustainability reporting

In today's environment, nearly all human activities are susceptible to digitalisation. For businesses, from engaging with stakeholders to regulatory compliance, digitalisation offers opportunities to enhance convenience, efficiency, while also introducing risks (Park, 2021). One way or another, digital innovations have the potential to reshape the structure of industries and can be highly disruptive (Christensen and Raynor, 2003).

Nonetheless, few studies have explored the role of digital transformation in sustainability reporting practices (Lombardi & Secundo, 2020; Schmitz & Leoni, 2019). Moreover, the adoption of digital tools varies widely across the ecosystem. For example, the adoption of digital tools is highly dependent on how small businesses strategically approach digital transformation (Quinton et al., 2018).

There is also an increasing demand for standardised sustainability information, driving the development of new reporting tools to enhance the reliability of disclosed information (George & Schillebeeckx, 2022). Such initiatives aim to mitigate potential issues with standardisation, such as lack of comparability and reliability, while improving the speed of delivery time and verification of information (Leitner-Hanetseder & Lehner, 2022).

An exemplary case of how digital tools can improve sustainability reporting is seen in the adoption of extensible business reporting language (XBRL).

XBRL is an international digital business reporting standard managed by a global not-for-profit consortium (XBRL), that facilitates the integration of both human-readable and structured, machine-readable data in a single document. Leveraging extensive markup language (XML), XBRL enhances comparability with other standards, including well-established financial reports, and promotes a universal language for disclosing information (Troshani & Rowbottom, 2022). Expected benefits of XBRL adoption include improved accessibility, data availability, reduced administrative burdens, and enhanced usefulness (Bartolacci et al., 2021).

XBRL exemplifies the digitalization's process of converting originally performed without computers into digital formats. This ranges from transitioning printed reports into PDFs, publishing reports across multiple online platforms, to employing digital tools for data collection, analysis and evaluation.

3.2. Sets of digitalization tools

This section addresses the role of digitalization in promoting the adoption of sustainability reporting among SMEs and EMDEs. Most of the tools discussed are related to the XBRL and GRI reporting standards, although

other insights have been drawn from other frameworks such as EU CSRD, IFRS, and TNFD. Illustration of use cases are sourced from the ecosystem of services offered to organisations to facilitate sustainability reporting, particularly those emphasizing open and accessible solutions.

Open vs. closed standards

The establishment of standards for sustainability reporting inherently drives digitalization. However, as highlighted in preceding sections, the adoption of these standards remains challenging for small and medium-sized enterprises (SMEs). This is primarily because standards provide a structured framework that ensures consistency and comparability across different entities and sectors, thereby facilitating the integration of digital tools and platforms to support the efficient sustainability data collection, analysis, and disclosure (Trum, 2020).

For SMEs, this entails access to affordable or even open-source solutions that simplify the process of collecting and reporting sustainability data, thereby reducing the burden and costs associated with manual data handling and reporting (Han and Kühnen, 2013). Standards can also streamline the compliance process, making it easier for SMEs and EMDEs to adhere to legal and regulatory requirements without requiring extensive additional resources.

Nonetheless, a significant advantage gap exists between the adoption of closed and open standards. Open Standards are publicly available and freely licensed for anyone seeking to use (FSFE, 2024). They are generally free or low-cost, making them accessible to organisations with limited resources such as SMEs and EMDEs. Furthermore, open standards foster innovation and competition among software developers to create diverse digital tools and solutions that adhere to these standards, offering SMEs a broad array of options tailored to their specific needs and capabilities.

Moreover, open standards are also present in the definition of digital public goods, defined in the UN Secretary-General's Roadmap for Digital Cooperation, as "open-source software, open standards, open data, open AI systems, and open content collections that adhere to privacy and other applicable best practices, do no harm, and are of high relevance for the attainment of the United Nations 2030 Sustainable Development Goals (SDGs)" (UN, 2024). SDGs)" In practice, open standards are not only DPGs in themselves, but play a critical role in ensuring interoperability,

promoting an open digital ecosystem, and the strengthening of other DPGs - particularly for software and AI systems.

Closed standards, on the contrary, are proprietary standards controlled by specific entities. While they can ensure a high level of specificity and potentially offer advanced features, their adoption might be limited to organisations capable of bearing associated costs. For SMEs, closed standards might pose a barrier to entry due to the higher expenses involved in acquiring necessary software licences or tools. Moreover, the lack of alternatives could hinder the organisation's ability to find a solution that precisely meets its unique reporting needs and constraints.

One example of an open standard driving digitalization is XBRL. XBRL is used in over 50 countries, by more than 600 member organisations, from both the private and public sectors (XBRL, 2024). At early stages, XBRL provides a common language for representing the contents of reporting statements. Subsequently, XBRL offers open digitalization tools that can be adopted by others, enhancing confidence in publishing reports and interoperability between different information systems, even across disparate organisations.

Open standards also enhance the value of sustainability reporting across various stakeholders, which greatly benefits for large corporations (though not necessarily to small ones, due to their comparatively limited scale). For regulators, open standards simplify the analysis of complex performance and harmonize risk information (e.g., or harmonising reporting obligations). For companies, they facilitate seamless information exchange within supply chains. For reporting service ecosystems, open standards increase available information, enabling the development of new and diverse solutions, and expanding the range of software offerings from vendors large and small.

Lastly, open standards promote vendor-neutral, platform-independent solutions. They can be adopted and adapted by a large number of solution providers, and even supported by not-for-profit or government-funded initiatives.

Taxonomies

Taxonomies, known as digital taxonomies in sustainability reporting field, are domain-specific dictionaries that define specific concepts (e.g. "net

profit"), their attributes, rich metadata, and their interrelationships (Wagenhofer, 2024).[6] Characteristics of a robust taxonomy include uniqueness, utility, independence, conciseness, and consistency. They promote standardisation by enhancing documentation (encouraging the free use of a rule, guidelines, or definitions), repeatability (ensuring consistent output quality), and acceptance (promoting convergence among different stakeholders) (Lucarelli et al, 2020).

The design of taxonomies entails a **decision-making process** that includes defining the reporting object (e.g. scope or rationale), identifying reporting roles involved in the reporting (e.g. who reports, who decides, who collaborates), outlining functional requirements (e.g. data requirement, data hierarchy, intended data uses), specifying technical requirements (e.g. data modelling and testing), and managing the lifecycle (e.g. versioning, notification, communication). As such, taxonomies move beyond basic data gathering methods toward a blend of information and digitalization tools.

Designing taxonomies is a complex and varied effort, posing challenges for SMEs and EMDEs (Allen & Overly, 2024). Typically, these organisations rely on taxonomies defined by others, raising alerts about the need to adjust expectations that can cater to both large and small to medium-sized organisations. Given the role of voluntary reporting within larger supply chains involving SMEs and EMDEs, taxonomies require adjustments to ensure inclusivity and avoid excluding organisations from the reporting process.

A critical feature of taxonomies is the use of **metadata**, information primarily intended for computer-based reading. Metadata includes multilingual labels, links to authoritative definitions, and validation rules, amongst other elements. While metadata is usually not directly visualised in reports, its association with reporting data enables enhanced data reuse, external modelling and validation. For SMEs and EMDEs, the use of metadata significantly enhances the reuse of their generated data across various data processing contexts.

Another characteristic of taxonomy is **versioning** (Ramanan, 2023). Taxonomies undergo regular update cycles, which can be required to correct errors (e.g. typos), formatting issues (e.g. data mask format),

[6] For the purposes of this paper, we refer to "taxonomy" as "digital taxonomy". For a more detailed explanation of the term in other fields of knowledge, please refer to the introduction.

adapt to changes of context (e.g. reinterpretation of taxonomy use) or resolve conflicts (e.g. clarification of different taxonomies overlap). Consequently, each taxonomy release is associated with a specific release date. Similarly, taxonomies often serve s foundational elements for creating new ones, leveraging existing components as an alternative to replicating or redoing modelling when an acceptable solution has been developed. This approach enhances data interoperability and ensures compatibility across different reporting frameworks.

Taxonomy can also distinguish between **mandatory attributes and optional information**, which ties directly to the modularity discussed earlier. Mandatory fields are essential for calculations and validations and can potentially halt data submission if omitted. Examples include manually filled (e.g. total assets) or automatically generated fields (e.g. submission dates). Voluntary fields provide additional context that aids in validation checks. While mandatory taxonomies increase process complexity, they reduce solution's applicability. Conversely, voluntary fields can reduce data comparability, and escalate reporting costs and complexity.

Another relevant aspect is that taxonomies utilize customised software processes, or **Extensible Markup Language (XML)**, adhering to international standards (e.g. W3C1 standards) to provide both vocabulary and unambiguous representation of reported information. Adopting XML, especially internationally standardised formats, can enhance data cleanliness and accuracy, and reduce reporting time (Bonsón et al, 2009). However, the variety of XML technical format necessitates technical expertise to select the most suitable format for an organisation's specific needs.

Lastly, taxonomies form the base for design systems that offer both human-readable and structured, machine-readable data, or inline solutions. These tools simplify human validation of inputted data (e.g. by presenting an easy-to-read layout with verifiable information), while simultaneously enabling automated calculations, validations, and chart generation.

Digital input methods

The collection, insertion and analysis of sustainability data can be achieved through various methods, each with different levels of accessibility for SMEs and EMDEs.

For organisations with limited internal resources, **online forms-based approaches** provided by regulators, or third parties are often the most viable option. One advantage of this approach is its straightforward data input process, as well as simplified comparability of end results. Additionally, it enables easy validation of inputted data for errors. However, a notable disadvantage is its lack of customization, as it tends to offer a "one size fits all" solution for data collection. Moreover, its low interoperability between systems necessitates manual rekeying and copy-paste pasting, which are time-consuming, costly and error-prone.

Alternatively, more flexible involve the development of **intermediary data-gathering solutions**. These solutions can be internally developed using existing software, or outsourced through contracted services. A related approach is the adoption of "bolt-on tools", which integrate with commonly used software, such as mainstream data and word editors (e.g. FactsConverter, Arkk XBRL Adapter, Firesys.de, Toppanmerrill). This method offers greater customization and benefits from a wide range of off-the-shelf solutions that can be tailored, especially for small and medium-sized organisations. However, challenges include higher demands on human and financial resources to ensure standardized information production, as well as potential long-term vendor lock-in with closed system solutions.

Examples of data-gathering solutions available for hire include:

- Regulatory and statistical reporting solutions, including tools for data collection, validation, and preparation of both quantitative and qualitative reports, as well for calculating risks and managing regulatory KPIs and templates (notable platforms in this category include regnology.net, Amana, Amelkis, Calcbench, MDD Platform, UBPartner).
- Sector-specific solutions, such as those designed for various sectos such as insurance (e.g. FactsConverter, parseport), banking and finance (e.g. aSISt, ParsePort XBRL Finance, Vizor) and tax reporting (e.g. SmartTaxBalance).

- Collaborative solutions designed to facilitate supply chain collaboration (e.g. IRIS FinX, IRIS Carbon) or consumer participation (e.g. Ez-XBRL Solutions).

Data ledgers

Data ledgers, utilizing advanced technology like blockchain, are digital databases designed to securely record information in an immutable and transparent manner. These ledgers can encompass diverse data types ranging from financial transactions and asset ownership to detailed records of a company's environmental, social, and governance (ESG) activities within sustainability reporting.

One of the primary benefits of data ledgers is enhanced **transparency and trust**. These tools provide a transparent record of transactions and data entries, visible to all authorized participants, allowing stakeholders to swiftly trust the accuracy of the sustainability information reported by a company, as data entered the ledger cannot be altered without clear notation or public acknowledgement.

Immutability is another critical advantage, as we consider that information recorded on a data ledger is inherently associated with content and time validation. This feature ensures the integrity of the data over time, making data ledgers an ideal platform for documenting and verifying sustainability claims.

Data ledgers can also contribute to efficiency and **automation**. Operating on a decentralised network, they distribute data across multiple nodes (computers). This decentralised approach reduces the risk of data manipulation, loss, or tampering, as no single entity has control over the entire network. It also enhances data security and resilience against cyber-attacks. Finally, data ledgers facilitate automation through smart contracts, which are self-executing contracts with terms directly encoded into code. This automation can significantly reduce the administrative burden and costs associated with manual data collection and reporting processes, making sustainability reporting more accessible and manageable, especially for SMEs.

An example of an open data ledger is the XBRL Global Ledger (XBRL, 2024), which serves as a standardised platform for capturing, archiving, transmitting, operational data and data definitions. These ledgers can

assist and automate audit review, facilitate data consolidation, enable seamless transfer of transactional accounting data between systems, and due to their open format, ensure advanced levels of interoperability with other solutions.

Data ledgers can also integrate with **APIs** (Application Programming Interfaces), enabling straightforward computer-to-computer communication. APIs are based on a set of protocols, routines, and tools used to build software applications, and facilitating communication between them. In the context of enhancing reporting through data ledgers, APIs play a crucial role in streamlining the integration of ledger technologies with existing business systems and processes. They also enable real-time access to data stored on the ledger, allowing organisations to include up-to-date sustainability information in their reports. This capability is particularly beneficial for dynamic and rapidly changing metrics, such as energy consumption or carbon emissions, where timely data is crucial for accurate reporting.

APIs can incorporate robust **security measures**, including encryption and authentication protocols, ensuring secure data transfer between the ledger and reporting systems. This security is vital when handling sensitive sustainability data and maintaining stakeholder trust. Organisations also utilize APIs to develop customised reporting tools and dashboards tailored to their specific needs, highlighting critical sustainability metrics and insights that are most pertinent to their stakeholders.

4. The role of digital transformation

We can draw a line on how digital technologies impact organisations, namely splitting transformation in two major categories: digitalisation and digital transformation (Collin et al., 2015).

Digitalization, as addressed in the section above, refers to the process of converting tasks originally performed without computers into digital formats. This includes activities such as converting printed reports into PDFs, publishing reports online across various platforms, and employing digital tools to collect, analyse and evaluate data. However, the more

advanced application of technology aims not only for digitalization, but also digital transformation.

Digital transformation entails leveraging technological principles and advantages to alter how processes are conceived and executed. For example, it promotes the adoption of Digital Public Infrastructures (DPIs) and Digital Public Goods (DPGs), where DPIs (Digital Public infrastructures) facilitate basic functions essential for public and private service delivery, promoting access to private and public services, and DPGs (Digital Public Goods) can be used for the systems that make up the components of digital infrastructures and therefore make use of open standards when designing DPIs.

But why does digital transformation matter for sustainability reporting?

According to the Oslo Manual (OECD, 2018), innovation refers to "a new or improved product or process (or combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)". Moreover, OECD Business Innovation Indicators (OECD, 2023) shows that the innovation gap between the most and least innovation-intensive sectors is significant, ranging from 40% and 50% depending on the indicator measured. In the same direction, over one-third of innovative firms report at least one innovation with environmental benefits.

Within this framework, technology plays a pivotal role, where the emergence of new information technologies and how they influence new business models is closely linked to the role of global value chains, the increasing importance of knowledge-based capital and economic impacts.

The adoption of innovation can vary in speed (Rogers, 1962), involving an individual process concerning how the adopting organisation becomes aware, takes interest in, evaluates, tries, and finally adopts or rejects a given innovation (Park, 2020). Digitalisation is strategic for companies (Quinton et al. 2018; Ukko et al. 2019), although it is risky for small business owners to assume that new technologies will automatically provide confer a competitive edge (Thompson et al., 2013). Nevertheless, corporate reporting over time has expanded the scope of information disclosure, initially targeting shareholders, then potential investors

(Gilmore and Willmott 1992), and ultimately broader audiences (Crowther, 2012).

The potential benefits of digital innovation are extensive. According to Bini (2019), positive trends include enhancing the ability to track progress against specific targets, facilitating the implementation of environmental strategies, enjoying reputational benefits, identifying cost savings, increasing efficiency and boosting staff morale. However, there are also reasons to approach digital innovation with caution, such as uncertainties about its organisational advantages, lack of customer interest, cost concerns, and challenges in gathering consistent data across operations and selecting appropriate indicators (Bini, 2019).

All those arguments for or against digital innovation pose significant challenges, particularly within the context SMEs and EMDEs (Pizza, 2023). In this regard, despite recent reports from leading consulting firms indicating widespread of new accountability tools, there is limited evidence regarding the uptake of digital technologies in sustainability reporting (EY, 2022; KPMG, 2020). Indeed, Small companies face unique challenges such as issues with institutional governance, smaller market sizes, and overlapping regulatory burdens.

4.1. Sets of digital transformation tools

Asset tokenization

Asset tokenization refers to the process of converting rights to an asset into a digital token on a decentralised ledger, such as those supported by blockchain technology. This approach provides a secure and efficient method of representing ownership of physical or intangible assets in a digital form. Blockchain's ledgers ensure decentralised and immutable asset tokenization, enhancing transparency, tamper-proof record-keeping and trust while reducing fraud.

To illustrate how asset tokenization can enhance sustainability reporting, we can review a key difference between crypto assets (like Bitcoin) and normal assets (such as national currencies). When reporting on national currencies in a bank account, we always report on the total amount of fungible assets available (e.g. the bank account balance) but never on the individual assets used to calculate the overall balance.

In a different direction, reporting on Bitcoin assets involves detailing each individual asset, even if the "coins" are potentially fungible. As such, the "account balance" of tokenized assets represents the cumulative total of individual assets, with each asset being uniquely identifiable. In other words, tokenization allows reporting on the total amount of fungible assets, or the identification of each asset alone. Traditional accounting methodologies, however, only allow reporting on the total balance of fungible assets, without providing details on individual assets components.

For sustainability reporting, asset tokenization offers the significant advantage of reporting assets (whether fungible or non-fungible) at both a granular and aggregate level. Due to the digital nature of tokenized assets, this means that each asset can be utilized for implementing off-chain (e.g. legal contracts) rules.

As of June 2022, tokenization had been regulated in 12 countries (Kumat, 2022), which led to a significantly diverse ecosystem. Both for-profit and non-profit solutions have emerged in response, including DexStar[7] (which tokenizes debt positions in sustainable projects), Cashlink[8] (which provides a supply chain crypto securities register, compliant with local regulations), Agrotoken[9] (which transforms grains into digital assets for storing/exchanging inputs, services and other assets), Moss[10] (which offers NFTs representing ownership of Amazon rainforest land), CarbonMark[11] (an open-source carbon credit marketplace), Regen[12] (which unites stakeholders to govern ecological outcomes and reward verified ecological achievements) and EthicHub[13] (which connects unbanked smallholder farmers with global lenders), amongst others.

Examples of asset tokenization related to sustainability reporting include:

- *Tokenization of Carbon Credits*: Companies can tokenize carbon credits, representing a reduction in carbon emissions, which can then be traded on blockchain platforms. This approach enhances transparency and traceability in carbon trading, encouraging more businesses to offset their carbon footprint. If sustainability reporting

[7] https://dexstar.io/
[8] https://cashlink.de/en/
[9] https://www.agrotoken.com/en/home
[10] https://www.rwa.world/rwa/moss
[11] https://www.carbonmark.com/
[12] https://www.regen.network/
[13] https://www.ethichub.com/

taxonomies include carbon credits, it becomes possible to track the movement of each credit or associate specific carbon credits with particular rules.

- *Tokenization of Sustainable Real Estate*: Tokenizing shares in green buildings or sustainable real estate projects allows investors to own fractions of environmentally friendly properties. This approach lowers the barrier to entry for investors interested in green real estate, thereby fostering the development of more sustainable building projects. Standardised reporting of real estate assets can be used to increase trust and reduce financial transaction risks.

- *Waste Management Tokens*: Blockchain technology can be used to tokenize the recycling process, where tokens are awarded to individuals or companies based on the amount of waste they recycle. These tokens can be redeemed for rewards or discounts, incentivizing sustainable waste management practices. If sustainability reporting includes details on waste management practices, the recycling material supply chain can be tracked at a granular level.

- *Sustainable Supply Chain Tokens*: Companies can tokenize their supply chains to ensure transparency and sustainability from production to delivery. Tokens can represent compliance with environmental standards at each stage of the supply chain. Consumers can then verify the sustainability of their purchases, encouraging companies to adopt greener practices. If SMEs integrate tokenization into their sustainability reporting, downstream supply chain participants can reuse the generated information, enhancing transparency and accountability.

In Brazil, the Central Bank is advancing towards asset tokenization through the “Digital Real”, branded officially as Drex. Drex represents a decentralised ledger system with potential applications of smart contracts, extending beyond programmable central bank-issued digital currencies (CBDCs), improving the security and efficiency of digital payments and ensuring the robust functioning of the payment system (Boar and Wehrli, 2021).

Drex currently operates with varying degrees of programmability. Currently in its pilot phase, it consists of APIs that enable standardized access by other applications. Considering the topics addressed in the

previous section, this phase primarily focuses on digitalisation rather than digital transformation. Nonetheless, the upcoming phases of Drex will introduce the ability to link token ownership with smart contracts, enabling the association of monetary and non-monetary information (such as those reported in taxonomies) with decision-making commands (if/then scenarios) (LIFT, 2024).

Platformization

The “platform effect” denotes the economic and strategic advantages brought about by digital platforms that facilitate direct interactions among multiple user groups, such as consumers, service providers, and producers. Platforms are solutions designed to generate value by enabling interactions among external actors (Parker, 2016).

Unlike linear production value systems, where value flows in a direct path from producer to consumer, platforms create value through enabling these various groups to interact, share, and transact directly, often in a many-to-many fashion. This model harnesses network effects, where the value of the platform increases with the addition of more users, significantly boosting scalability and efficiency. This shift to platforms involves three primary transformations: (1) orchestrating resources by positioning producers and consumers as the main assets; (2) facilitating external interactions among external producers and consumers; and (3) focusing on ecosystem value by maximizing the overall value of a growing ecosystem through a circular, iterative, feedback-driven process (Sarkar, 2016).

Platformization carries substantial implications for SMEs, offering both advantages and challenges (Cenamor, 2019), with digital transformation capabilities being crucial to capitalise on these opportunities (Min, 2021).

On the positive side, platforms increase the value of SMEs’ products or services by expanding the network of users. Also, as the network expands, the cost of servicing each additional user typically decreases, allowing SMEs to benefit from economies of scale. For EMDEs, there are additional opportunities for new entrants to leverage on network effects and establish a dominant position in their market.

However, creating platforms requires significant capital investments, which can be resource-intensive for SMEs. Moreover, SMEs may become

increasingly reliant on network effects, which can diminish rapidly. Several big techs are usually associated with the platform effects, including those focused on logistics (e.g. driver or delivery services), asset lending (e.g. housing and second-hand goods), marketplaces (e.g. consumer or business intermediaries), amongst others.

Examples of platform effects relevant to sustainability reporting include:

- **Sustainability-driven Marketplaces:** Platforms that connect consumers with sustainable products can see increased value for all users as the number of participants grows, enhancing the range and quality of available sustainable options. This enhances the potential for reputational gains from investing in and publicly reporting voluntary sustainability efforts.

- **Lowered Barriers to Entry:** External small producers or service providers of sustainability reporting services can more easily gain access to new markets, bypassing traditional intermediaries. Platforms also match supply with demand more efficiently, reducing entry costs for market segmentation, and sector-specific service design. This expands the range of products and services available for SMEs to utilize, thereby improving the delivery of sustainability reports.

- **Improved data utilisation**: Platforms can enhance resource utilisation and increase returns on data production investments. The collaborative nature fosters innovation and facilitates the sharing of sustainable technologies and best practices across industries and consumer bases.

- **Sustainability-driven supply chain platforms**: These platforms provide transparency into supply chains or are structured around circular economy principles. They assist stakeholders in making informed decisions about SME sustainability. For example, platforms can track a product's lifecycle from raw materials to disposal, increasing access to data on carbon footprint, water usage and labour practices across the supply chain. Platforms can also support the exchange, reuse, and recycling of sustainability data.

A key debate surrounding platformization and its effects revolves around the role of large platforms, such as those categorize under European Law as "gatekeepers"[1]. According to the Digital Markets Act (DMA), these are defined as major online platforms and digital services that serve as critical

intermediaries between businesses and consumers. Typically, these entities wield significant market power and control over user access. The DMA specifically targets these gatekeepers by imposing a set of rules intended to ensure fair competition, spur innovation and prevent market abuse (Beems, 2022). Its ultimate goal is level the playing field for smaller businesses and enhance consumer protections in the digital realm.

Platform solutions specifically designed for sustainability reporting are still in nascent stages. While some all-in-one software solutions are available for SMEs, offering digitalization capabilities, they do not necessarily promote the network effects characteristic of platformization. Instead, they tend to operate within closed infrastructures, where last-mile product and service consumption remains the most expected behaviour.

Nevertheless, current digital solutions provide services including data collection and management, emissions reporting, stakeholder facilitation, information dissemination, and more. Consequently, these existing solutions can drive platformization and support circular economy initiatives (Eastwod, 2023), either by connecting knowledge through online and offline platforms (e.g. Be.Brussels[14]), fostering community links (e.g. PeaceCircular[15]), reusing sustainability reporting data for monitoring purposes (e.g. Circular Economy Platform[16]), enhancing sustainability credentials (e.g. Provenance[17]), or tracking circular economy practices int the food chain (e.g. IBM Food Trust[18]), among others.

Artificial intelligence

Artificial Intelligence (AI) encompasses the development of computer systems capable of performing tasks typically requiring human intelligence. These tasks include learning, reasoning, problem-solving, perception, and language understanding. According to the OECD, “an AI system is a machine-based system that, for explicit or implicit objectives, infers, from the input it receives, how to generate outputs such as

[14] https://www.circulareconomy.brussels/
[15] https://pacecircular.org/
[16] https://www.cep-americas.com/
[17] https://www.provenance.org/
[18] https://www.ibm.com/products/supply-chain-intelligence-suite/food-trust

predictions, content, recommendations, or decisions that can influence physical or virtual environments" (OECD, 2024).

AI solutions can be broadly categorised into two types based on functionality: descriptive AI and predictive AI.

Descriptive AI is the one that has become popular, and focuses on analysing historical data to understand patterns, trends, and relationships. It does not predict future outcomes but rather provides insights into what has happened in the past, hence its "descriptive" label. An example within sustainability is the use of AI to analyse energy consumption patterns in a facility over time, identifying peak usage periods and potential inefficiencies. Examples include SustainLab[19] (which integrates 500+ sustainability reports for visualisation and informed actions), Nasdaq Sustainable Lens[20] (which offers on-demand data-driven insights to over 9,000 companies), Greenomi[21] (which evaluates compliance CSRD and EU Taxonomy), among others.

Predictive AI methodologies forecast outcomes based on past trends and are widely known due to the applications of Natural language processing (NLP), and LLMs (Large Language Models). LLMs are trained on vast amounts of text, visual or audio data, to generate look-like data that mimics human-like understanding of language. Several companies offer closed solutions of LLMs (such as those offered by global tech giants) while numerous open AI models are also available (Solaimna, 2023).

For example, LLMs contribute to enhancing sustainability reporting by highlighting key sustainability performance indicators, navigating through complex sustainability regulations and standards, customising sustainability reports to the interests and concerns of various stakeholders and even creating interactive Q&A tools for stakeholders to ask specific questions about a given organisation's sustainability practices. They can also demonstrate a sound grasp of language nuance, as well as a strong appreciation of the audience in reports, when compared to reports generated solely by humans (Villers, 2024).

There is nonetheless a risk of bias against smaller actors. According to the OECD (2023), AI provides a new tool for investors to harness big data for aligning investment standards. However, the use of AI in automatised

[19] https://sustainlab.co/
[20] https://www.nasdaq.com/solutions/corporate-esg-solutions/resources/fact-sheets/esg-ai
[21] https://www.greenomy.io/

portfolio allocations could exclude developing countries due to insufficient high-quality data needed for sustainability reporting.

For SMEs designing their own solution of AI presents a significant challenge. Training AI from scratch is prohibitively expensive and demands datasets that are frequently larger than what most small or medium enterprises possess. However, it is feasible to adopt pre-trained AI services, as well as cost-effectively fine-tune models to meet a given organisation's needs. Some solutions involve straightforward tasks, such as granting access to organisational reports, while others require more complex programming tasks but can deliver customised compliance checks, or thematic vocabulary refinement.

Nevertheless, AI applications in sustainability face several challenges: (1) overreliance on historical data in machine learning models, (2) uncertain human behavioural responses to AI-driven interventions, (3) heightened cybersecurity risks, (4) potential adverse impacts of AI applications and (5) complexities in measuring the outcomes of intervention strategies (Nishant, 2020).

Additionally, a notable challenge is the fact that most data used for AI training originate from large organisations, resulting in an underrepresentation of SME data in training datasets (Chan, 2013). Moreover, AI technology struggles with accurately distinguishing inputs from different sources with varying levels of reliability (Ferreira,2009).

Interoperability and digital public infrastructures

Data interoperability refers to the ability of various information systems, devices, or applications to access, exchange, integrate, and cooperatively utilize data in a coordinated manner. It encompasses more than just data-related aspects, such as portability or integration, including, for example, aspects like data governance, standards, or market dynamics.

For example, interoperability can be used to integrate reporting across diverse data sources, including those originated from IoT devices, regulatory databases, and third-party sustainability metrics. Interoperable data also allows organisations to benchmark their sustainability performance against industry standards or competitors, and facilitates efficient compilation, analysis and reporting of data in compliance with government bodies and sustainability rating agency

requirements. Moreover, it facilitates stakeholders engagement by providing transparent and accessible information, thereby supporting better governance, innovation, and transparency.

Interoperability empowers more environmental initiatives within businesses (Mora-Rodriguez, 2016), and XBRL is a prime example of how interoperability enhances both inside-out and outside-in perspectives on sustainability reporting and management. However, recent literature review posits that although integrated reporting has emerged as a growing trend in the industry, the use of the technology is still in its infancy. Also, interoperability is associated with conflicts of interest for companies, leading to Greenwash-pitfalls and inadequate enforcement of sustainability and transparency practices (Seele, 2016).

Another approach for interoperability is seen in digital public infrastructures (DPIs). DPIs refers to sets of digital systems, tools, and platforms that provide public goods or services through digital means. The definition of DPIs can vary based on infrastructure's purpose (e.g., financial inclusion, access to information), the technologies involved (e.g., digital identity systems, payment platforms), or governance and operational models. Also, when the definition emphasizes the openness of the provided solutions, they can also be categorised as DPGs (Digital Public Goods), constituting an avenue to promoting greater interoperability of data, suppliers and information (DPGA, 2024).

DPIs are designed to benefit the broader public, often underpinning critical aspects of society such as governance, economy, and social welfare. Key sectors leveraging DPIs include digital identity systems, digital public records (such as land registries), healthcare services and electronic access to health records.

Specifically tackling environmental challenges and climate change, one illustrative area is deforestation (Attah, 2024). For example, MapBiomas addresses sustainable land-use mapping. This collaborative initiative provides ultra-detailed, open source maps of Brazil, focusing on issues such as deforestation, water levels, crop cover, and ecosystem restoration. Similarly, Planet Labs[22] offers millions of satellite images regularly, enabling near-real-time monitoring of deforestation areas. Sustainability reporting data, if properly tokenized and digitally managed, can facilitate the integration of relevant satellite images by organisations.

[22] https://www.planet.com/

A promising area that connects sustainability reporting to DPGs is the increasing demand for open and accessible weather, climate, and hydrological data (DPGA, 2022). While open data is becoming more readily available, innovative data infrastructure is required to unlock the access to a greater diversity of actors in the ecosystem (Farooqi, 2023). For example, Moja Global[23] specialises in collecting, analysing, and sharing sustainability reporting data to pinpoint areas of significant environmental impact and support the development of mitigation strategies, facilitation the measuring, reporting, and verification of greenhouse gas emissions and removals from agriculture and forestry. In Armenia, all automatic meteorological stations nationwide were interconnected to provide weather forecasts and meteorological monitoring in a free, open and accessible way (Sakahayan, 2022).

There are compelling reasons to integrate existing DPI components, such as digital identity, digital payments and data exchange, to environmental challenges (Sandman & Wood, 2024). For example, digital payments, when linked to social protection systems, can enable pre-emptive cash assistance by directing targeted funds to affected populations ahead of an extreme weather event.

An illustrative list of how DPIs and data exchange systems can enhance sustainability reporting data is detailed in a report by the UN Environment Programme (2024):

[23] https://moja.global/

DPI as a data exchange system for sustainability-related data	
Technology innovation	**Desired outcome**
Data markets for environmental sustainability-related data	Real-time monitoring of deforestation with data readily available for stakeholders by creating incentives for collecting and sharing. This process is expected to bring about consistent and reliable data across the board
Open data discovery for environmental sustainability	Facilitate identification of relevant data
Privacy enhancing technologies to enable flow of environmental sustainability information	Addressing the barriers for data sharing without compromising privacy
Using Large Language Models to "speak" with green and circular economy policy	Improved compliance with environmental standards across all company sizes due to better understanding and easier policy interpretation
Computational law and data integration of green and circular economy policy measures	Streamlined MRV frameworks that reduce redundancy and confusion among stakeholders
Data markets for environmental sustainability-related data	Data-driven policy making by creating incentives for data collecting and generation
Open data discovery for environmental sustainability	Facilitate identification of relevant data
Data markets for environmental sustainability-related data and tools and techniques for human-centred artificial intelligence in environmental sustainability decision-making	A more inclusive data environment that represents diverse groups and allows for user-friendly interaction with data-generating and collection tools

For SMEs, DPIs and DPGs can significantly lower entry barriers to accessing various services at a fast pace. An illustrative example is Pix in Brazil, which is a DPI for digital payments that has reduced costs for users and promoted financial inclusion. Within little over a year of its launch, Pix was adopted by 67% of adults in the country. In this context, SMEs are serviced by publicly owned and oriented services. Indeed, crucial to Pix's success is the dual role of the central bank as both infrastructure provider and regulator (Duarte, 2022), as well as the collaboration fostered between the public and the private sectors (Wilkens, 2022).

It is also noteworthy that governments are increasingly mandating data interoperability, particularly in response to the limited effectiveness of voluntary arrangements. The EU Data Act, for example, establishes rights to access and use data generated in the EU across all economic sectors, facilitating data sharing, especially industrial data, while the EU Interoperable Act creates a network of digital public administrations that stimulates public sector innovation and encourages public-private partnerships (European Commission, 2024).

5. Recommendations

A. Adopting reduced and flexible standards for SMEs to ensure proportionality and avoid unnecessary costs.

Considering that:

- The increasing complexity of financial reporting standards poses a challenging scenario for SMEs, and the introduction of mandatory sustainability reporting associated with financial reports tends to further exacerbate the compliance gap.
- Ensuring proportionality in the application of standards to SMEs is crucial.
- International standards worldwide are in early stages of adapting requirements to meet the needs of SMEs and EMDEs.

Recommendations:

- **Conduct public consultations led by international organisations and governments to gather insights into SMEs' sustainability reporting needs.** Moreover, proactive support is paramount to encourage SME participation in the process.
- **The development of standards for SMEs must reduce the complexity and costs of sustainability reporting, through flexible requirements, reported in a simplified manner.** Smaller companies allocate fewer resources to generating sustainability data, and overly complex standards may compromise data quality and SMEs' competitive edge.
- **Employ a building block approach to tailor viable, flexible requirements, based on each SME's unique characteristics**.

B. Capacity building of SMEs and EMDEs for sustainability reporting, including international support for knowledge sharing.

Considering that:

- For a variety of reasons, SMEs and EMDEs are lagging behind in the development of sustainability reporting and, as a result, have not benefited from its value-enhancing features.
- Access to expert staff in sustainability reporting is limited for SMEs and EMDEs, resulting in high implementation costs.
- The lack of adequate sustainability reporting may impede SMEs and EMDEs' access to needed sources of sustainable finance.

Recommendations:

- **National economies should focus on creating programs aimed at building SMEs' capacity to generate proper sustainability data,** enhancing their competitiveness across global value chains.
- **International efforts and technical cooperation programs should promote capacity building across EMDEs,** to reduce bottlenecks in accessing sustainable development funding.
- **Lead firms shall play a crucial role in providing qualification throughout their value chains.** Utilizing their structures, lead companies are strategically positioned to connect players, enhance the capacities of different actors, and alleviate the reporting burden on SMEs and EMDEs.

C. Leveraging to <u>decrease</u> the cost for SMEs and EMDES in generating sustainability reporting data.

Considering that:

- Standardised processes ensure better-structured, consistent, and comparable data across different sectors, thereby facilitating the efficient collection, analysis, and disclosure of good sustainability data.
- Standard platforms and taxonomies simplify the process of collecting and reporting sustainability data, reducing costs associated with manual data handling and reporting.
- XBRL illustrates how international standard taxonomies lower information-gathering costs, although these may still be high for SMEs.

Recommendations:

- ***Promoting open taxonomies offer a beneficial path for reducing costs and promoting a healthy ecosystem for sustainability reporting.*** Open taxonomies provide a common language that can be adopted by many, enhancing interoperability between diverse information systems, even in altogether different organisations.

- ***Large-scale, low-cost digital input methods can lower the cost for SMEs to adopt digital sustainability reporting solutions, up to a certain level.*** However, although costs for reporting data can be lowered, investments related to understanding the data, the organisational strategy, and the meaning of sustainability reporting remain challenging for SMEs.

- ***Data ledgers can reduce the cost of republishing data, especially when reporting comparable data in different jurisdictions or sectors is required.*** They enable the settlement of data lakes or spaces, facilitating compliance. However, data ledgers require advanced understanding of digital taxonomies, which SMEs often lack.

- ***Platformization can drastically reduce data generation costs, especially with foundational digital public infrastructures (DPIs) like digital identity or payments.*** Several stages of sustainability reporting require common processes to be completed, such as tracking authorship, information access permission, and payments. These can be streamlined with national DPIs, making governments the main suppliers of DPIs of this type for sustainability reporting.

- ***The adoption of PETs (privacy enhancing technologies) can reduce the costs of controlling commercially sensitive information, increasing trust in sharing data***. By allowing data to be exchanged between known and unknown peers, without disclosing its content except with proper access permission, PETs can protect sensitive information on transit, increasing trust in the system, which leads to more information being shared in the value chain data.

- ***AI, in particular generative AI and LLMs, can greatly reduce costs of understanding and generating sustainability reporting data***. AI can help change how SMEs interpret and respond to policy measures, by improving policy comprehension and allowing users to query policy data. LLMs can lower the costs of applying sector specific formats or help to navigate through large and complex groups of policies and

procedures, making it easier for SMEs to make queries, assess data quality, generate insights, and receive tailored assistance.

D. Leveraging technology to increase the value of sustainability reporting data generated by SMEs and EMDEs.

Considering that:

- Large actors are more likely to profit from sustainability reporting data, due to their larger capacity to make use of large amounts of data, and their privileged position at the top of data value chains.
- SMEs have economic incentives to profit from sustainability reporting data, such as access to sustainability funding, reduced insurance costs, direct profit from carbon markets, or even indirect increases in competitiveness. Those activities, nonetheless, are heavily data dependent, which burdens SMEs.
- The use of new digital technologies has increased data value in other sectors, including the financial sector (e.g., the role of crypto assets), supply chain (e.g., the role of AI optimisation), and public service (e.g., the role of digital ID for reducing bureaucracy).
- The use of data ledgers provides transparency and trust in data sharing. When integrated with distributed technologies, they enhance data immutability, automation, and API (Application Programming Interfaces) usage, allowing simple computer-to-computer communication.

Recommendations:

- **Asset tokenization can increase the traceability of granular and material data published in sustainability reports.** If SMEs have easy access to tokenizing valuable information in their reports, they can profit beyond the report as a whole, increasing the opportunities for received value. Also, if assets of reports are tokenized, the growth of public and free information expands access to data demanding opportunities, such as green funding and affordable insurance.
- **Asset tokenization can also increase the value of sustainability reporting in the data value chain**. If reports are tokenized, they can be negotiated with larger companies as paid information. With the use of wallets and smart contracts, the reuse of their data can lead to

later profitability, as happens with “royalties” or “copyright”, which fund the early value chain actor that pays to generate an information, but which is later paid back for their initiatives.

- **Asset tokenization can create middle-markets of sustainability revenues for SMEs.** For example, tokenizing shares of a sustainable real estate project enables investors to own a fraction of the asset, lowering entry barriers for green agenda investments.
- **Asset tokenization can enhance the consumer perceived value of sustainability reporting.** Companies can tokenize their supply chains to ensure transparency and sustainability. Once made public and accessible, consumers can verify the sustainability of their purchases, increasing the brand or product value. This approach is particularly beneficial in contexts where mandatory data publication in news venues is required, a format lacking data interoperability and utility for asset tokenization.
- **Data interoperability can facilitate the creation of data spaces, pools or lakes – technical repositories of data that incentivize the responsible and profitable reuse of data by third parties**. By scraping the web, several sustainability reports can be aggregated and analysed. Scraped data, however, breaks the link between data producer and data user, removing incentives for data producers to publish their data with granularity and completeness beyond legal obligations. New models of data repositories can include rules and governance systems that preserve the data producer-user relationship, ensuring stability and alignment.
- **The use of data interoperability with smart contracts can streamline consented third-party access to company-specific data.** Electricity or gas bills, for example, contain valuable information for sustainability reporting and are largely provided to companies by service providers in digital format. If end-users of data value chains, such as banks, want to have access to this information in real time, smart contracts can allow companies to give or revoke consent for the operation, protect sensitive information in data transference, and set up payments and other forms of retributions related to data usage.

E. Improving the sustainability reporting service ecosystem

Considering that:

- Developing and maintaining input systems, data ledgers and other technologies are costly, and SMEs lack the capacity to fund access to these technologies alone.
- A diverse and inclusive reporting services market is essential for generating sustainability data across different sectors and company sizes.
- There are currently few free or open solutions for SMEs and EMDEs to deliver sustainability reporting, while existing paid solutions need to scale up to continue providing digital services.

Recommendations:

- **Promote free and open technologies to meet SME's sustainability reporting needs**. The most promising investments currently lie in open standards and taxonomies. Moreover, comprehensive digital input methods for all data reporting phases are essential for companies to fully benefit from sustainability data markets. Open standards encourage platform-independent, vendor-neutral markers and align with the digital public good (DPG) concept supported by the UN Secretary-General's Roadmap for Digital Cooperation.
- **Digital public infrastructure can bolster private and non-profit business models for sustainability reporting services.** By simplifying the use of digital IDs and payments systems, these infrastructures enable service providers to concentrate on their core business and cater to a more diverse clientele.
- **Large companies should be required to contribute back to the data generated by SMEs along the data value chain**. In general, there are no incentives for large actors to pay or incentivize smaller actors' data gathering. However, implementing a compulsory incentive for the reuse of sustainability data within supply chains can generate revenue to fund a more robust intermediary ecosystem.
- **Utilizing AI infrastructure, such as public LLM topic-enhanced solutions, can foster the availability of "AI reporting as a service"**. Open AI layers fine-tuned for sustainability reporting can make data-gathering and reporting more accessible to SMEs, thereby reducing costs and improving efficiency.

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