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**Engineering and Management**

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# Sustainability Strategies in High-Tech Companies: Supply Chain Management, Green Information Systems, and Green Innovation

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# Abstract

As all of us can see, nowadays companies are no longer approaching sustainability as a matter of compliance alone, but as a driver of innovation, competitiveness, and long-term value creation: sustainability has evolved from a secondary matter to a core element of business strategy. This thesis investigates how high-tech companies in Italy are integrating sustainability into their strategies. In particular, we will focus on sustainable supply chain management, green innovation, and the role of Green Information Systems.

The analysis is based on a combination of quantitative and qualitative data gathered through questionnaires and interviews posed to the representatives of seven Italian companies operating in the high-tech sector. The results show the importance for the companies of implementing a Green Information System, as it could serve as a key tool for reducing information asymmetry, ensuring compliance with social and environmental regulations, and improving transparency about emissions and other social metrics throughout the supply chain. Also, this tool could be a base on which more innovative strategies could be built, such as Eco-design, blockchain, and advanced data analysis techniques.

The study identifies several barriers that impede the effective implementation of sustainable practices. These are the complexity of global supply chains and high-tech products, the absence of technical standards, and the frequent lack of traceability and verification mechanisms for information provided by suppliers: these limitations often undermine companies' efforts to assess and improve their impact.

The thesis concludes by underlining the need for coordinated action from both the private and public sectors. Companies must commit to long-term investments in digital tools and skills for environmental data management, while policymakers must develop international technical standards: this combined effort is necessary for overcoming the existing obstacles to sustainability and truly integrating this aspect into business strategies.

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# Introduction

As companies seek to grow, they must navigate an evolving economic landscape where sustainable development is becoming a fundamental pillar of corporate strategy. This ongoing shift presents businesses with both increasingly stringent regulatory requirements and competitive opportunities: in fact, companies that successfully integrate sustainability into their operations can not only ensure compliance with environmental and ethical standards but also strengthen their long-term market position.

This thesis aims to explore corporate sustainability strategies, especially the use of Green Information Systems focusing on the implementation status within some high-tech companies operating in Italy. The central research question guiding this investigation is: *"How do high-tech companies develop and implement sustainability strategies, across areas such as regulatory compliance, supply chain sustainability, green information systems, and innovation?"*

In this context, sustainability refers to the integration of environmental, social, and economic dimensions into business practices. It involves not only ecological responsibility but also social inclusion, respect for human dignity, and economic viability.

The analysis focuses on companies operating within the high-tech sector. While there is no universally accepted definition of a high-tech firm, the term generally refers to industries characterized by the production of goods or services with a high degree of technological innovation. These sectors often experience rapid technological advancements and dynamic competitive environments. Industries commonly classified as high-tech include pharmaceuticals, aerospace, medical devices, precision instruments, information and communication technologies, computing, biotechnology, and nanotechnology (Ramaciotti, High Tech, 2012).

This sector presents unique sustainability challenges, including product complexity, globally extended supply chains, and significant environmental and ethical concerns related to raw material sourcing. Many critical materials originate from regions with weak labour protections and minimal environmental regulations, creating challenges for companies striving to comply with European sustainability requirements. Ensuring ethical sourcing remains particularly difficult due to the limited availability of viable alternatives. Given these complexities, effective sustainability management requires robust data collection and analysis to ensure compliance and certification of components across their supply chains. As the well-known principle states, *"If you can't measure it, you can't manage it*." Using Green Information Systems, companies could systematically track, assess, and optimize their sustainability performance to ensure compliance and drive meaningful

improvements. Moreover, the sector is inherently innovation-driven, and we expect a growing portion of this innovation is expected to address sustainability challenges. Investigating how companies address these challenges and leverage sustainability as a competitive advantage is, therefore, highly relevant.

Before diving into the analysis, the thesis will first present the theoretical foundations of the study. Chapter 1 introduces agency theory and the problem of information asymmetry, explaining how Green IS can help reduce gaps between companies and their stakeholders when it comes to sustainability information. Also, the chapter ends by presenting the UTAUT applied to Green IS, to explain the adoption patterns of this tool in organizational contexts.

Chapter 2 offers a review of the academic literature on Green Information Systems and sustainability strategies, with a focus on the high-tech sector. Then, Chapter 3 outlines the methodology used in the research. Chapters 4 to 6 present the result of the analysis. Chapter 4 maps out the main sustainability strategies observed in the sample, firstly with a lexical analysis, followed by the results of the questionnaires. In Chapter 5 the identified strategies companies adopt are presented, while Chapter 6 focuses on the obstacles and challenges that companies face in executing them. Chapter 7 looks at the maturity of the strategies in place, comparing company performance and evaluating them.

The conclusion (Chapter 8) summarises the key findings and reflects on the limitations of the study, with suggestions for policymakers and companies interested in improving their sustainability.

# 1. Theoretical Framework

## 1.1 Basic Concepts: Agency Theory and Asymmetric Information

Agency theory is an economic concept introduced by Jensen and Meckling (1976) that examines the delegation relationship between a principal and an agent. As defined by the authors, an agency relationship is a "contract under which one or more persons *(the principal(s))* engage another person *(the agent)* to perform some service on their behalf, involving the delegation of certain decision-making authority." A classic example is when shareholders entrust the company's management to managers, who are expected to act in the shareholders' best interests.

However, conflicts of interest can arise if there is a misalignment of goals or risk preferences between the principal and agent. For example, the manager may prefer enhancing the value of the company in the short-term, even taking some risks, and then going to work in another one, while the equity owners are more interested in keeping the long-term value of the firm high, pursuing a more secured strategy.

Agency theory seeks to identify the types of contracts and incentives that can align the interests of principals and agents, minimizing the risk of opportunistic behavior. The costs associated with this relationship, known as agency costs, can be divided into three categories (Jensen et al., 1976):

1. Monitoring expenditure: Expenses incurred by the principal to monitor the agent and prevent unwanted actions
2. Bonding expenditure: Expenses incurred by the agent to assure the principal that any harmful actions will be avoided
3. Residual loss: The loss in the principal's welfare due to the agent's decisions diverging from those that would optimally serve the principal's interests

If an agency contract is not properly managed, the resulting costs can be significant, and the situation may become unfavorable for both parties involved.

Conflicts tend to increase in the presence of information asymmetry, when one party holds more complete or detailed information and chooses not to share it with the other fully. In such cases, cooperation or decision-making may become irrational due to the uneven distribution of information between the two sides (Wang, 2024). This imbalance weakens the principal's ability to ensure that the agent consistently acts in their best interest. Information asymmetry is at the core of the typical problems found in agency relationships. Depending on when it occurs, it can lead to two main issues: adverse selection and moral hazard.

Adverse selection arises before the contract is signed when the agent has private information about their own characteristics or the project the principal does not possess. This phenomenon was explained by George A. Akerlof(1970) in *The Market for "Lemons",* where he showed how uncertainty about product quality could lower the average quality on the market and even cause market failure. Similar dynamics can be observed in many other situations as well.

Moral hazard, on the other hand, occurs after the agency relationship has been established when the principal cannot fully monitor the agent's actions. This leads to what is known as post-contractual opportunism: the agent may take advantage of the lack of oversight to pursue their own interests, even at the expense of the principal. For instance, a manager (acting as the agent) may reduce their effort, make excessively risky decisions, or even behave unfairly, knowing that they will not bear the full consequences of their actions, which will instead fall mostly on the principal (Wang, 2024). In general, agency theory recommends the use of proper monitoring systems and incentive mechanisms to reduce opportunistic behavior by the agent and better align the interests of both parties once the relationship is in place (Jensen et al., 1976).

## 1.2 Agency theory in the context of sustainability

The traditional agency relationship arises when shareholders (*principals*) delegate the company's management to managers (*agents*). From a sustainability perspective, this relationship broadens to include additional stakeholders such as employees, consumers, suppliers, and the broader society in which the company operates.

When dealing with sustainability issues, the complexity related to agency problems and information asymmetry becomes even greater when adopting a broader perspective, such as Stakeholder Theory (Freeman & McVea, 2005). Stakeholder Theory suggests that companies shouldn't focus exclusively on shareholders' interests but should simultaneously address the expectations of various groups including employees, customers, suppliers, local communities, and society at large. These stakeholders are recognized as legitimate principals with valid interests, and under the same theory, addressing their needs could lead to positive economic success (Freeman & McVea, 2005).

These new subjects face an even greater challenge regarding information asymmetry, as they typically have less access to accurate information on the actual environmental, social, and governance (ESG) impacts of corporate activities compared to shareholders.

When reporting sustainability data or declaring environmental and social objectives and outcomes, the company naturally has more detailed information than external stakeholders. Moreover, there

might be cases where a company intentionally withholds or even falsifies such information to appear more sustainable than it is, especially when its sustainability performance is low or below expectations. This situation can lead to adverse selection: due to information asymmetries, companies with weaker sustainability practices may be incentivized to present themselves as sustainable, while truly committed companies might be unfairly disadvantaged. For instance, investors looking to allocate capital to sustainable companies often rely on ESG ratings. For instance, investors often rely on ESG ratings to select sustainable companies. However, due to a lack of standardization and differences among rating agencies, unsustainable firms sometimes receive higher ratings than genuinely sustainable ones (Lu, 2024). Another notable example is greenwashing, where consumers willing to pay premium prices for sustainable products might be misled by companies falsely presenting their products and services as eco-friendly. These deceptive practices could erode consumer trust in this type of market and as a result, harm truly sustainable businesses (de Freitas Netto et al., 2020; Szabo & Webster, 2021). It has been observed that some investment funds joining sustainability initiatives such as the UN PRI attract greater capital inflows without actually improving their ESG practices, suggesting that firms and funds may emphasize their sustainability efforts more for financial or reputational gains than out of genuine commitment (Kim & Yoon, 2023).

Information asymmetries in this type of agency relationship can also lead to moral hazard. In these instances, a company might misrepresent itself as more sustainable to secure certain advantages, counting on the inability of principals to fully monitor its actions. Examples include misusing funds obtained for sustainable projects, assuming that investors or entities providing the funding cannot fully supervise the company's activities. In particular, they could lie initially to appear more environmentally responsible and attract finance but later fail to implement promised sustainability standards or even pressure regulators to weaken environmental rules (Wilson, 2010). Similarly, there is the issue known as "green moral hazard," where applying a new technological solution for a problem could increase environmentally harmful behaviors (Wagner & Zizzamia, 2022).

## 1.3 The role of green information systems in reducing asymmetric information

As discussed in Section 1.1, sustainability initiatives often face classic principal-agent problems due to information asymmetry. Also, Stakeholder theory emphasizes that transparent information flows are crucial to aligning the diverse interests around the sustainability goals of shareholders,

customers, regulators, and communities. In this light, robust Information Systems emerge as crucial tools for enhancing transparency and trust in sustainability practices.

A specific instance of this application is represented by Green Information Systems (that will be called Green IS in this thesis), which are systems created to gather, collect, manage and elaborate data specifically related to sustainability, such as greenhouse gas emissions, energy usage, water consumption, material sourcing and social indicators. A more detailed discussion of Green IS, along with its benefits, challenges, and other innovative technologies built upon it, will be presented in Chapter 2. Before this, Section 1.4 introduces the Unified Theory of Acceptance and Use of Technology (UTAUT), with some examples of applications to the specific case of GIS from the literature, which helps explain how and why organizations could adopt these systems.

## 1.4 UTAUT for Green Information System

Unified Theory of Acceptance and Use of Technology (UTAUT) provides a useful theoretical lens to better understand how Green Information Systems (Green IS) can be successfully adopted within organizations This theory, defined by Venkatesh et al. (2003) and developed integrating multiple existing theories, explains how users accept and utilize technology within organizational contexts. It identifies four primary factors that influence technology adoption:

1. Performance Expectancy: the degree to which individuals believe that using the technology will enhance their job performance or produce significant benefits or it is better than the precedent technologies.
2. Effort Expectancy: the ease of use associated with the technology, reflecting perceptions of how straightforward and user-friendly it is. Technologies that users believe are intuitive, straightforward, and require minimal effort to learn and use tend to achieve higher adoption rates.
3. Social Influence: it captures the extent to which individuals perceive those important others, such as colleagues, managers, industry peers, or social groups, believe they should use a new technology. Social norms and organizational culture greatly influence individuals' willingness to adopt and use technological solutions.
4. Facilitating Conditions: these refer to the resources, infrastructure, and technical support available within the organization or context that assist and facilitate the use of the technology. This dimension addresses aspects such as adequate training, organizational support, access to resources, and compatible infrastructures.

Moreover, the original UTAUT model identifies four moderating variables - Gender, Age, Experience with technology, and Voluntariness of use - that influence the strength of these relationships. Specifically, it appears that users who are younger, male, more experienced with technology, and using it voluntarily typically have a higher intention to adopt the technology.

In the context of Green Information Systems, Anthony et al. (2020) proposed an adapted version of the UTAUT model, tailored to identifying several the key determinants influencing GIS diffusion:

1. Performance Expectancy:
    - Human Infrastructure: Organizational staff's environmental awareness and their attitudes toward sustainability; how much employees genuinely care about environmental issues.
    - Administrative Policies: Internal regulations and rules governing an organization's everyday processes. The greater the emphasis these policies place on sustainability, the higher the likelihood of successful GIS adoption.
2. Effort Expectancy:
    - IS Strategy: Clarity and robustness of an organization's strategic procedures for deploying information systems. Organizations with well-defined and transparent IS strategies find it easier and less complex to integrate and disseminate GIS practices.
3. Social Influence:
    - IS Infrastructure: Available technological resources, such as servers, networks, hardware, and software, essential to achieving organizational goals. A robust infrastructure greatly facilitates the diffusion of Green IS practices.
    - Knowledge Accessibility: Availability and distribution of information regarding Green IS implementation across the organization. A shared, accessible repository of sustainability-related information increases awareness and encourages GIS adoption.
4. Facilitating Conditions:
    - Institutional Pressure: External influences, such as governmental regulations, market pressures, and societal expectations, significantly drive GIS adoption.

This study also found age to be an influential moderator, with younger executives showing higher intentions toward GIS adoption compared to older counterparts. However, gender, education, and experience did not significantly impact adoption intentions. Successful GIS adoption was also linked to improvements in organizational sustainability practices such as Green Design, Green Production, Green Procurement, Green Operation, and Green Disposal, areas integral to corporate sustainability strategies (see chapter 3: sustainable supply chain management, eco-design).

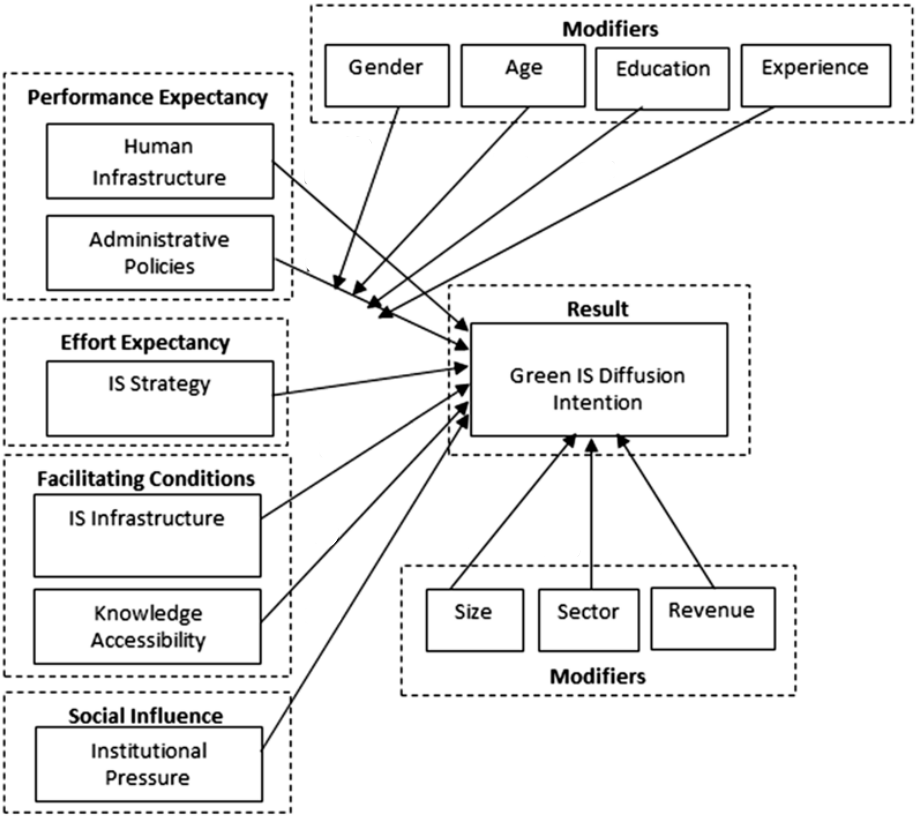


*Figure 1. Green IS structural model – Adapted from Anthony et al. (2020)*

Shahzad et al., (2022) further expanded the UTAUT model specifically for sustainability by incorporating two additional factors derived from UTAUT2:

- Green Hedonic Motivation: Intrinsic pleasure and satisfaction derived from using sustainable technologies positively influence intentions to adopt green innovations.
- Green Innovation Cost: Perceived financial implications of implementing green innovations significantly influence organizational adoption intentions.

Their findings demonstrated that these two additional dimensions, combined with traditional UTAUT constructs, substantially impact organizational intentions and the actual adoption of green innovations, validating their relevance in sustainability-focused contexts.

Moving beyond specific GIS contexts, Nakandala et al. (2024) applied the UTAUT framework to general technology adoption by examining managerial intentions toward Industry 4.0 technologies. They integrated managers' digital expertise and environmental consciousness alongside traditional UTAUT constructs, finding that both digital expertise and environmental consciousness significantly increased intentions toward adopting Industry 4.0 technologies. Perceived usefulness plays a crucial role in technology adoption; when stakeholders recognize the benefits of a technology, they are more likely to adopt it and feel satisfied with its performance. So, while new technologies could help in obtaining higher environmental performance, an inconsiderate implementation could result in to increasing costs, and lower stakeholder trust: if stakeholders do not perceive technology as valuable, they may become dissatisfied and lose trust in the company that adopts it (Lee et al., 2003).

Finally, Park(2020) employed the UTAUT model to examine blockchain technology adoption within logistics and supply chain companies. This study confirmed that core UTAUT constructs, Performance Expectancy, Effort Expectancy, Facilitating Conditions, and Social Influence, significantly affected organizational intentions and attitudes toward blockchain adoption, further reinforcing the applicability and utility of UTAUT in analyzing technology adoption within sustainability contexts.

# 2. Sustainability Strategies in the High-Tech Sector

## 2.1 Literature Review

A literature review is necessary for any research because it helps identify well-established findings and gaps related to the topics under investigation. This section focuses on previous research regarding how companies manage environmental, social, and economic responsibilities the sustainability strategy they apply, and how Green IS supports it through digital innovation.

The study will concentrate mostly on companies operating in high-tech sectors. These sources provide insight into the methods and technologies that support responsible business practices, revealing various approaches used to balance profitability with ethical and ecological considerations.

To do that, a research process has been performed in Scopus using keywords such as “strategy,” “green information systems”, “big data”, “sustainability”, “sustainable supply chain”, and other related keywords. Only articles published within the last ten years and appearing in reputable journals have been chosen, to ensure up-to-date and credible insights.

## 2.2 Corporate Sustainability Strategies

The role of sustainability in companies has evolved significantly over the years, moving from a marginal concern to a central pillar in many corporate strategies. In particular, high-tech companies have increasingly embraced sustainability in response to factors such as regulatory requirements, stakeholder demands, and heightened consumer awareness of environmental concerns. As consumers become increasingly conscious of ecological issues, integrating sustainability principles into corporate strategies not only helps mitigate environmental impact but can also generate economic benefits (Shaik et al., 2024).

In recent years, organizations have recognized the importance of green knowledge management, the process of the acquisition, storage, sharing, and use of environmental knowledge, while green technology innovation, together with Green Information Systems, has emerged as a critical driver of corporate environmental performance (Cheng et al., 2023; Sahoo et al., 2023; Singh et al., 2024). Green IS, in particular, integrates digital solutions with sustainability objectives, enabling more effective collection, analysis, and use of sustainability-related data.

Moreover, businesses that commit to these strategies can enhance operational efficiency, reduce waste (Sahoo et al., 2023), and strengthen their brand reputation among both consumers and

investors (Shaik et al., 2024). Especially when sustainability is seen as a strategic imperative rather than a simple obligation coming from customers and legislation, companies find ways to become competitive in an evolving global market. By integrating green innovation into its strategy, thus developing a green innovation strategy, a company can fulfil market requirements and norms while reducing the impact on the environment and increasing its financial performance (Marini Purwanto, 2024).

## 2.3 Sustainability Strategy through Green Information Systems

Green Information Systems (Green IS) refers to the use of information systems to enhance sustainability performance. This can be achieved through teleconferencing, auditing systems, automation, and more (Khan et al., 2021). These tools enable organizations to collect, manage, analyse, and apply “sustainability data”, which is the information that measures a company's environmental, social, and economic impact (IBM, 2024). Green IS is often confused with Green Information Technology, or Green IT. However, with this term, we refer to something substantially different. In fact, unlike Green IT, which focuses primarily on the environmentally conscious design, development, and maintenance of IT infrastructure (often described as "greening of IT"), Green IS goes further, using digital tools and data to support broader sustainability initiatives throughout the organization, known as "greening by IT" (Kirchner-Krath et al., 2024).

The concept of Green Data is broad, and it could be both qualitative, like supply chain information or workers’ feedback on labour conditions, or quantitative, such as carbon emissions, energy consumption metrics, or capital expenditure on sustainability initiatives. By gathering and analysing these data, companies, and institutions can better monitor their environmental and societal impact and make more informed decisions, ultimately benefiting both their revenue streams and society at large. Data studies show how having this information could help drive positive change, as it captures critical dimensions of a phenomenon, links them to real-world metrics, and lays the ground for in-depth analysis (Püchel et al., 2024). Also, Empirical evidence indeed links greater environmental disclosure to reduced information asymmetry, lower capital costs and higher stakeholder trust (Steindl et al., 2024)

Green IS has also been explored as a tool to encourage behavioural changes, particularly regarding resource consumption *(SDG 12),* sustainable transportation *(SDG 11*), and education about sustainable behaviour across dimensions *(SGD 13)* (Kirchner-Krath et al., 2024). However, it is

important to note that this happens, especially when the adoption of the instrument is voluntary and aligned with company culture (Kirchner-Krath et al., 2024).

However, the implementation of Green IS is not without its challenges. First, organizations struggle with "the lack of data accessibility, availability, and quality" (Püchel et al., 2024).

Moreover, collecting and storing large volumes of sustainability data can be itself resource and energy intensive, adding a layer of complexity to the overall environmental impact. This paradox highlights the need for efficient systems and usage.

Also, one final challenge is that data alone is not sufficient; its true value lies in how it is processed and interpreted. In this regard, Big Data techniques play a crucial role in extracting meaningful insights.

### *2.3.1 Big Data for Sustainability*

With the term Big Data, we refer to the enormous quantity of data that has been created, especially with the Internet applications, but also to the technologies created to manage and extract value from it. The use of Big Data requires massive resources in data centres, leading to increased energy consumption and greenhouse gas emissions. A huge amount of computational power and energy is required in the phases of generation, acquisition, communication, storage, and analytics (Wu et al., 2016). However, research shows that big data practices, like other technological innovations, can significantly help SMEs meet their sustainability goals (Shaik et al., 2024). In the last decades, we have seen an increasing use of these technologies for sustainability purposes. For example, Enel in its Isernia project, utilizes Big Data technologies to analyse real-time data from the smart grid, enhancing the efficiency and reliability of electricity distribution or Leonardo's CLEOS platform uses data from satellites to provide real-time access to vast geospatial datasets, enabling advanced analytics and AI-driven insights for applications such as land monitoring, infrastructure management, and precision agriculture. Also, they can help in tracking waste generation and disposal, making it possible to identify patterns. This could be used to make more efficient plans for waste production, which could incentivize recycling and reuse (Shaik et al., 2024). Additionally, Big Data technologies contribute to energy efficiency by precisely monitoring it. For example, ABB, the Swiss multinational, has developed the ABB Ability platform, which leverages cloud computing and Big Data analytics to monitor energy distribution systems. This solution enables the prediction of energy loads and the optimization of resource use, significantly reducing energy consumption in industrial infrastructures. Such technologies also contribute to enhancing energy efficiency,

demonstrating that Big Data management is a fundamental element in sustainability strategies. Nevertheless, it is essential to implement practices to mitigate its environmental impact. First, the impact of data centres must be reduced; this goal can be achieved through energy-efficient hardware, like the ones of Green Data Centers, that has improved cooling systems, and the use of renewable energy sources to power operations. Additionally, data reduction techniques such as lossless compression, deduplication, and filtering of redundant or irrelevant data can significantly decrease storage and processing needs, reducing energy consumption. Another effective approach is edge computing, which processes data closer to its source, minimizing transmission energy costs. Moreover, green software algorithms that optimize computing efficiency and reduce processing power requirements can contribute to sustainability. Lastly, AI-driven energy management systems can be used to predict and dynamically adjust energy consumption in real time, ensuring that resources are utilized efficiently (Wu et al.., 2016).

## 2.4 Sustainability Strategy through Supply Chain Management

When analysing the environmental impact of high-tech products, a good starting point is to examine emissions across the three scopes. Scope 1 refers to direct emissions from a company's operations, while Scope 2 encompasses indirect emissions from purchased electricity, heat, and steam—areas often within a company's closer control. Scope 3 covers emissions arising throughout the entire supply chain, extending from raw material extraction and manufacturing upstream to the product's use and disposal downstream. In the electronic industry, one of the most relevant of the high-tech sector, waste is generated at both ends of its supply chain: during production and at the end-of-life recycling stages. Upstream, the demand for inexpensive components has led suppliers to practices that cause significant water contamination and chemical pollution. Downstream, rudimentary and improper recycling methods for extracting valuable metals and materials have resulted in the release of substantial amounts of toxic substances, including mercury, lead, and cadmium, into the environment. Alongside social issues such as child labour and unsafe working conditions, environmental concerns, ranging from high greenhouse gas emissions and water pollution to deforestation, toxic waste, and biodiversity loss, add further complexity.

For companies operating in the high-tech sector, most emissions typically originate within the upstream supply chain, as shown in the Figure 2. For this reason, prioritizing sustainability in this area is essential for overall environmental performance (Technology Report 2023, Bain & Company). However, businesses set most of their goals on the reduction of emissions in Scope 1 and 2. That is

because the dynamics of the supply chain are outside of a firm's activity, so they are more difficult to control. Secondly, reductions in this area compete with other strategic priorities (Technology Report 2023, Bain & Company). Also, however, for the impact it has, it emerges the necessity for high-tech companies to have a more sustainable supply chain.

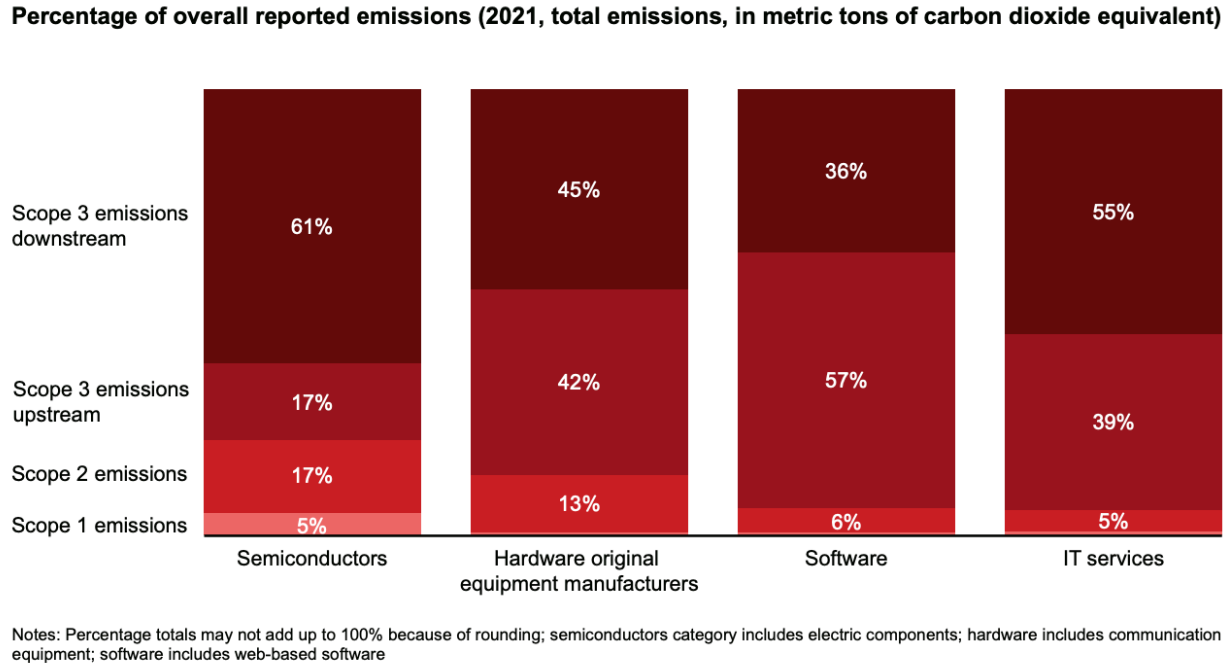


*Figure 2. Sources: CDP, Bain & Company.*

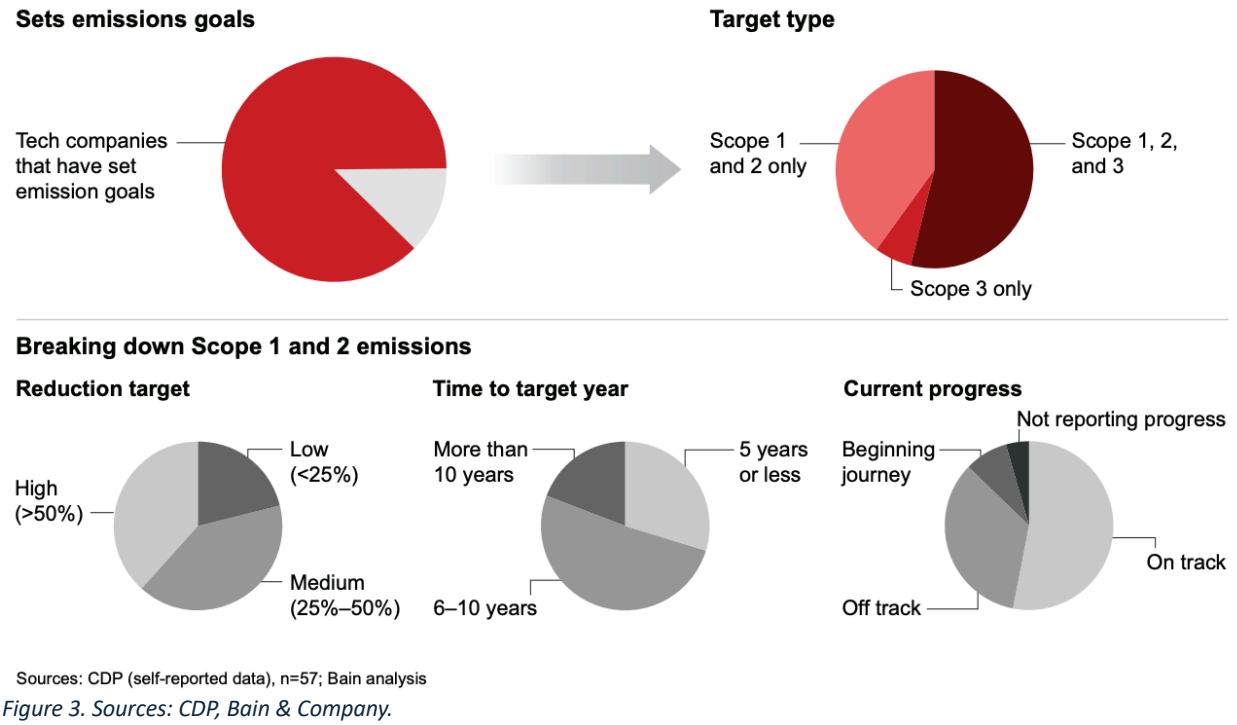


*Figure 3. Sources: CDP, Bain & Company.*

According to Linton et al., 2007) a supply chain is considered sustainable when it incorporates ethical, social, and environmental responsibilities into every phase, from raw material sourcing and transportation all the way through to end-user delivery and disposal. Achieving this ideal, however, remains a significant challenge. One problem is the “chain liability effect”: this means multinational companies may be held responsible for their suppliers' unethical or unsustainable actions, which can harm the company's reputation and operations (Wilhelm et al., 2016). This risk is particularly acute in multi-tier supply chains, as the most hazardous practices tend to occur among lower-tier suppliers, operating in less regulated contexts and remaining largely invisible to focal firms (Villena & Gioia, 2018), especially in the high-tech field. In fact, in this sector, companies rely largely on raw materials coming from regions that are particularly subjected to this issue. Although many companies mandate that direct, first-tier suppliers adhere to sustainable standards in hopes of creating a “domino effect” down the supply chain (Villena & Gioia, 2018), ensuring compliance beyond the first tier can be difficult. However, ensuring compliance with sustainability standards beyond the first tier remains highly complex. In this context, Green Information Systems play a pivotal role, offering the digital tools that enhance transparency and traceability across all tiers of the supply chain. In fact, the sustainable supply chain management is one of the primary domains where Green IS are most effectively applied. Through advanced digital platforms, companies can systematically collect data from suppliers, identify environmental and social risks along the chain, assess the sustainability performance of their partners, and take corrective actions based on accurate information. Moreover, these systems form the foundation upon which more advanced technologies, such as the blockchain. The following sections will explore in depth these topics: sustainable sourcing and ethical procurement, and blockchain for transparent and sustainable supply chains.

### *2.4.1 Sustainable Sourcing and Ethical Procurement*

Sustainable sourcing and ethical procurement are critical components of responsible supply-chain conduct in high-tech industries. Ethical procurement practices ensure that suppliers adhere to labour standards, minimize their environmental footprint, and promote social responsibility (Lambrechts, 2020). However, many suppliers, particularly those in lower tiers, face challenges in meeting these standards due to cost pressures, lack of enforcement mechanisms, and limited access to sustainable technologies. One of the key concerns in sustainable sourcing is the ethical treatment of workers. The industry employs millions of workers globally, with a high concentration in China

and ASEAN (Association of Southeast Asian Nations) countries. Many of these workers, particularly women, face low wages, excessive working hours, and precarious employment conditions. Temporary contracts and the lack of collective bargaining further exacerbate these challenges. Ethical procurement frameworks aim to address these issues by requiring suppliers to comply with international labour standards, such as those outlined by the International Labour Organization (ILO, 2024), and corporate social responsibility initiatives (ILO, European Union, OECD).

Environmental sustainability is another crucial aspect of ethical procurement. The production of electronic components involves hazardous materials, and improper disposal of e-waste contributes to pollution and health hazards. To combat these issues, sustainable sourcing strategies emphasize the reduction of hazardous substances, improved waste management, and the adoption of energy-efficient manufacturing processes. Certifications such as the Restriction of Hazardous Substances (RoHS) and ISO 14001 serves as a benchmark for evaluating suppliers' compliance with environmental standards (Nawrocka, 2008).


*Figure 4. ISO 14001's logo*


*Figure 5. RoHS's logo*

To strengthen sustainable sourcing, lead firms in the electronics sector are increasingly implementing due diligence measures. These include supplier audits, third-party certifications, and collaboration with local governments and non-governmental organizations (NGOs). Some companies have also developed supplier codes of conduct, which outline expectations regarding labour rights, environmental protection, and ethical business practices. However, enforcing these codes remains a challenge, particularly in regions where governance structures are weak or where suppliers prioritize cost reduction over compliance. The role of government regulations and international initiatives is vital in promoting sustainable procurement. Programs such as the United Nations Global Compact and the OECD Guidelines for Multinational Enterprises encourage corporations to integrate sustainability into their sourcing strategies. In China, initiatives like the Social Responsibility Guide and the Guide to Social Responsibility in the Electronic Information

Industry provide frameworks for companies operating in the electronics sector to enhance responsible procurement practices (Responsible Business in China Supply Chains, ILO).

Green Information Systems play a growing role in supporting ethical sourcing in high-tech supply chains, facilitating companies to manage supplier practices, and ensuring compliance with labor and environmental standards. In particular, they support ethical sourcing by enhancing visibility, enabling better supplier assessment, and facilitating compliance monitoring. Visibility means having a real-time understanding of what is happening across the entire supply chain; GIS could help in this by collect and integrating data from multiple sources, making it easier to trace the history of the materials. In terms of supplier assessment, GIS helps evaluate performance based on environmental, social, and ethical criteria. These systems provide structured scorecards and real-time dashboards, with which companies can compare suppliers, monitor improvements, prioritize those aligning with sustainability goals, and exclude the ones that are not. For compliance monitoring, GIS integrates data from various sources to track whether suppliers are meeting required standards over time, enabling quicker responses to violations and supporting more robust due diligence.

Some companies rely on software developed by specialized firms. Examples of these tools include EcoVadis, IntegrityNext, and Ecoinvent. EcoVadis (https://ecovadis.com/it/) is a leading sustainability ratings platform, used to evaluate suppliers based on environmental, social, and ethical criteria. It provides structured scorecards that help companies compare and monitor supplier performance over time. IntegrityNext (https://www.integritynext.com/) is a cloud-based solution, which allows businesses to automate the monitoring of ESG compliance across their supply chains, flagging potential risks using data from public sources, audits, and certifications. Ecoinvent (https://ecoinvent.org/), on the other hand, provides a detailed life-cycle inventory database that helps companies quantify the environmental impact of materials and processes, including carbon footprint and resource use.

*Figure 7. Integrity Next's logo*

*Figure 6. Ecoinvent's logo*

Figure 8. EcoVadis' logo

### *2.4.2 Blockchain for Transparent and Sustainable Supply Chains*

The blockchain is a digital ledger of transactions that is duplicated and distributed across the entire network of computer systems on the blockchain. Each block in the chain contains several transactions, and every time a new transaction occurs on the blockchain, a record of that transaction is added to every participant's ledger. This decentralized structure ensures that the data is transparent and secure, as altering any information would require changes to all subsequent blocks and the network consensus (IBM, 2024). With these characteristics, blockchain technology offers a decentralized, transparent, and secure method for recording transactions, making it a valuable tool for enhancing supply chain visibility and product traceability.

By implementing blockchain in supply chains, all participating entities, both upstream and downstream, can form a consortium. Within this framework, digital information about products, such as batch numbers, manufacturing and processing data, expiration dates, storage conditions, and transportation details, is immutably recorded on the blockchain during production. Compared to traditional traceability methods, blockchain technology can reduce supply chain risks more cost-effectively, expand the scale and scope of tracking systems, enhance trust and transparency among supply chain participants, and bolster consumer confidence in traceability information (Fan et al., 2022). Blockchain technology enhances trust and reliability within the supply chain network when combined with advanced technologies such as cloud computing, robotics, the Internet of Things (IoT), big data analytics, cybersecurity, and simulation-based prototyping (Kamble et al., 2023).

One potential and interesting application is reducing carbon emissions and ensuring the transparency of the carbon trade process (Sharma et al., 2020). Generally, adopting this technology can enhance the development of green information systems within firms, positively impacting their organizational performance (Khan et al., 2021). Indeed, blockchain serves as a useful tool for ensuring product quality and safety, ultimately helping companies achieve their sustainability goals. However, its use is not widespread. There are two main reasons: customers still do not know its superiority in data traceability, and the use of blockchain is complex and expensive (Fan et al., 2022). From a study, it appears that blockchain adoption in the supply chain largely depends on consumer awareness and their willingness to pay for traceable products. In this case, the cost should be shared among the three actors, the supplier, the manufacturer, and the retailer, with the manufacturer contributing primarily (Fan et al., 2022).

## 2.5 Sustainability Strategy through Green Innovation

Green innovation can be defined as the set of strategies, processes, and technological solutions aimed at reducing environmental impact and promoting sustainability within organizations (Marini Purwanto, 2024). As mentioned before, integrating green innovation into a company's strategy could help improve financial and environmental performance at the same time (Marini Purwanto, 2024). This is particularly interesting to consider in the high-tech sector, which has a main characteristic is the high level of innovation. Research shows that advanced technological innovations can significantly help also SMEs in meet their sustainability goals (Shaik et al., 2024).

Among these technological enablers, Green Information Systems represent the backbone of many green innovations. For example, innovations such as real-time monitoring of emissions, AI-driven energy optimization, and cloud-based platforms for supply chain transparency all rely on the capabilities offered by GIS.

A clear example is Verdigris Technologies, which offers an AI-driven platform that allows commercial buildings to monitor and optimize their energy consumption. By analyzing data from smart sensors, the system generates actionable insights that reduce energy waste and improve operational efficiency (Verdigris, p. https://www.verdigris.co/). Similarly, Microsoft is leveraging artificial intelligence to enhance environmental sustainability across its operations. As part of its goal to become carbon-negative by 2030, the company is investing in AI solutions to monitor and reduce energy consumption in its data centers, including the optimization of server workloads and cooling systems (Microsoft). In the same domain, Google has employed DeepMind's AI to optimize the cooling of its data centers, achieving energy savings of up to 40% for cooling purposes—demonstrating how advanced analytics can significantly reduce electricity consumption and related (Google, 2023). Amazon, on the other hand, developed an AI-powered packaging optimization engine that analyzes product characteristics and shipping combinations to minimize the size and materials used for packaging, which has led to the elimination of over two million tons of packaging materials (Amazon, 2022).

Meanwhile, Apple has developed Daisy, a robotic system capable of disassembling iPhones to recover valuable materials such as cobalt, rare-earth elements, and aluminum. These are then reused in new products, supporting a closed-loop production system and reducing the need for extracting raw materials emissions (Apple, 2019). In fact, also the literature shows thatIndustry 4.0 technologies could enhance circular economy practices such as reuse, recycling, remanufacturing, and also green procurement (Khan et al., 2021).

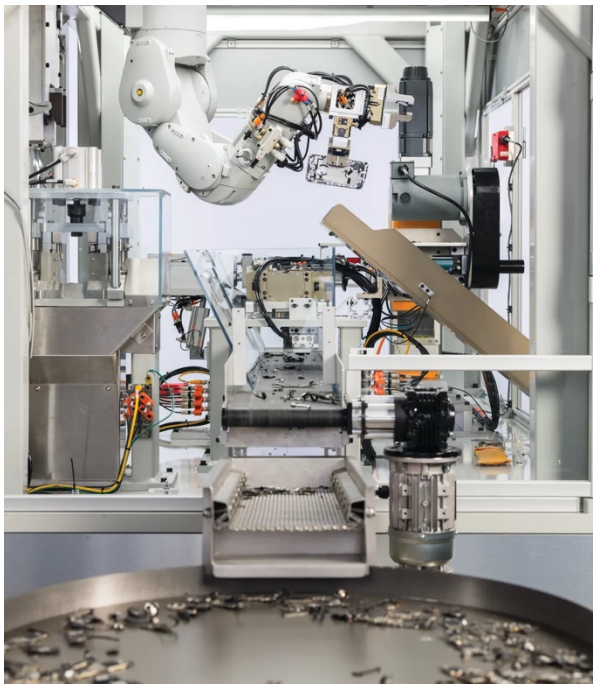

Figure 9. *Apple's Daisy, the recycling robot*

Green innovation is also evident in building design. Deloitte's Amsterdam headquarters, known as The Edge, is widely recognized as one of the world's greenest smart buildings. It integrates IoT sensors and AI to dynamically manage lighting, temperature, and space usage, resulting in a 70% reduction in energy consumption compared to traditional office buildings (Randall, 2015).

Figure 10. *The Edge, Deloitte's Headquarter - 1*

Figure 11. *The Edge, Deloitte's Headquarter - 2*

Green innovation includes advanced digital technologies, but also the integration of eco-design principles from the earliest stages of product development, which will be further explored in the following paragraph.

### *2.5.1 Eco-Design and Sustainable Product Development*

Design was first mentioned as a key element to improve sustainability in the early 1970s (Sharma et al., 2020). Over the following decades, it evolved from the early "green design" to "design for sustainability" and finally "design for circularity". In this context, Circular Economy emerged as a "system of production and consumption that focuses on maintaining products, components, materials and energy in circulation to maintain, add and recreate value as long as possible". In this model, the "end-of-life" is replaced by the reuse of the product, the recycling of parts, and the recovery of materials in a way that helps reduce the consumption of raw materials (Cisneros Chavira et al., 2023). It contrasts with the prevailing system of "linear economy," concentrating on recovery instead of extraction of new materials (Founding Partners of the Ellen MacArthur Foundation, 2013).

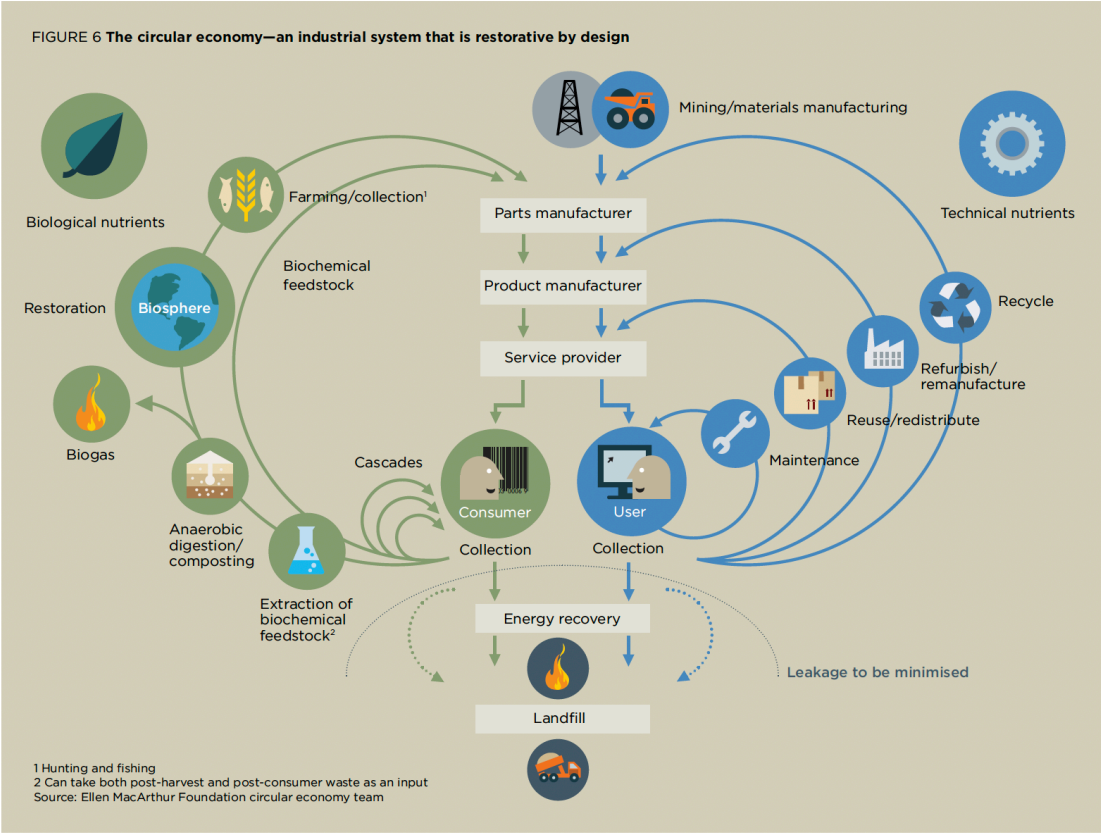


*Figure 12. Circular economy – the Butterfly Diagram. Source: Ellen MacArthur Foundation circular economy team.*

At the product level, strategies to enhance circularity include extending product lifespan, designing modular components, remanufacturing, reusing parts, and using fewer materials free of toxic chemicals, which can be recycled or composted. Regarding production, it includes adopting

renewable energy sources, optimizing processes and products for resource efficiency, and repurposing waste as a valuable input. (Cayzer et al., 2017). According to the Ellen MacArthur Foundation, additional principles include designing out waste, employing standardization and modularization, choosing feedstock based on circularity potential, promoting resilience through diversity, and operating under renewable energy while thinking in "systems" and cascades (Founding Partners of the Ellen MacArthur Foundation, 2013). New interesting merging approaches in this field include design for emotional durability, design for fault diagnosis, and design inspired by biomimicry (Cisneros Chavira et al., 2023). A common approach to eco-design is concentrating on durability; this approach helps most products, reducing the need for frequent replacements and the associated energy and material use. However, evidence shows extending a product's life cycle does not always result in a reduced environmental impact; in some instances, shorter-lived products can sometimes be more energy efficient, like freezers (Cisneros Chavira et al., 2023).

In companies, eco-design strategies can be applied adopting the 9R Framework. This model includes a hierarchy of actions: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, and Recover (Potting et al., 2017; Kirchherr et al., 2017).

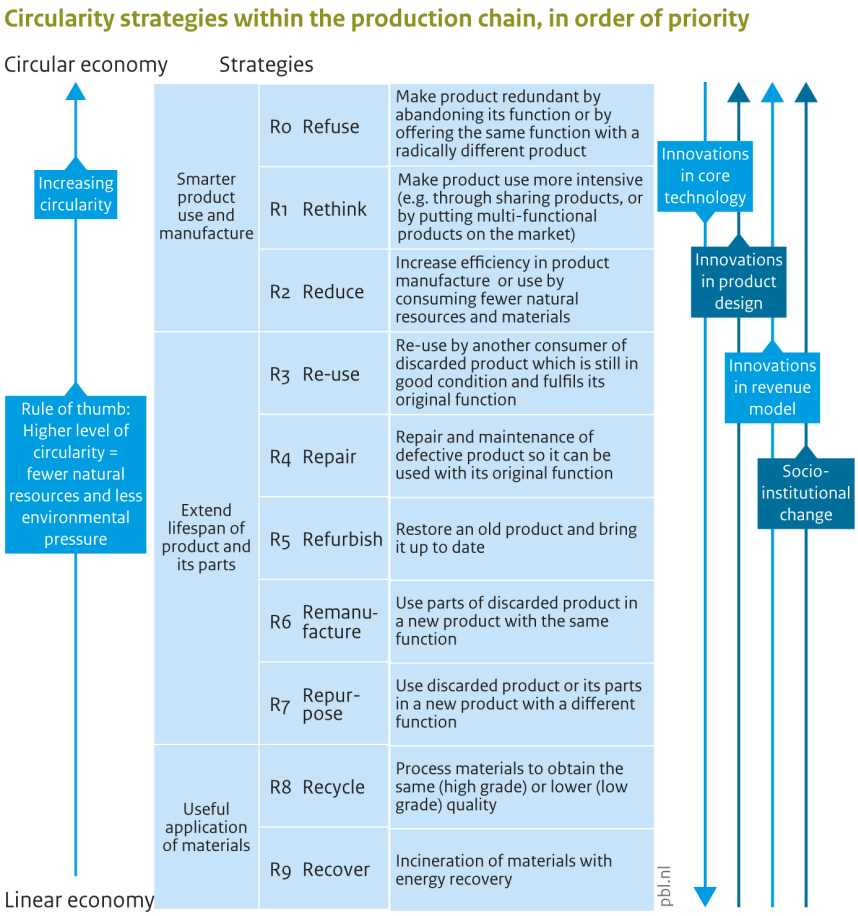


Figure 13. *The 9Rs Framework by Potting et al. (2017). Source: RLI 2015, edited by PBL (www.pbl.nl)*

Circular economy practices can be facilitated through Industry 4.0 technology: these interventions optimize, solve problems faster, and reduce the consumption of materials and energy (Cisneros Chavira et al., 2023). IoT and Big data analytics are especially useful in this context(Sharma et al., 2020).

Researchers have outlined various barriers to adopting eco-design. First, in most cases, the reliance on Industry 4.0 solutions and green IS, which not all companies have or can afford, or product designers can use. Another significant challenge is the high financial investment required, especially for these advanced technologies. Consumer behaviour also presents challenges, as reluctance to adopt new practices, such as, for instance, purchasing pre-used products, can slow progress. Furthermore, market entry costs and the limited economic viability of recycling often influence design decisions and value recovery processes, making widespread adoption more difficult (Cisneros Chavira et al., 2023).

# 3. Research Methodology

## 3.1 Introduction and general description of the sample

The primary objective of this analysis is to examine and compare the sustainability strategies of several companies operating in the high-tech sector. The sample of seven firms was inherited from a separate research project on the tracking of the electronics supply chain, in which a company was initially contacted to identify its suppliers. Those suppliers subsequently became the focus of in-depth interviews by a research team from Politecnico di Torino, whose findings have been provided to the author in the transcript format for secondary analysis. All interviewed companies operate in the high-tech market in Italy and have been anonymized to protect their confidential information.

## 3.2 Structure of interviews and questionnaires

Data collection from the companies was carried out through two main methods: questionnaires and interviews**.** The questionnaires, administered via SurveyMonkey, included questions based on a similarity (Likert-type) rating scale, along with one multiple-choice question.

The questions posed in the questionnaires are as follows.

---

1. *Green Information System adoption within the organization. For each of the following statements, please indicate your agreement on a 1 to 5 scale, where 1 indicates very low and 5 indicates very high.*
    a. *We formally track and report the environmental performance of our products and operations.*
    b. *We regularly track, monitor, and share environmental information within our company.*
    c. *We have a well-developed database to track and monitor environmental issues within our company.*

2. *Green Information System adoption within the supply chain. For each of the following statements, please indicate your agreement on a 1 to 5 scale, where 1 indicates very low and 5 indicates very high.*
    a. *We are able to respond to supply chain partners (both suppliers and customers) needs more quickly by sharing environmental-related information (e.g., amount of emissions or waste, energy consumption, etc.) with them.*
    b. *We openly share environmental information with our suppliers and customers*
    c. *We have an Information System through which environmental information flows seamlessly between the suppliers, manufacturers, and customers in our supply chain*
    d. *Our suppliers openly share environmental information with us*

e. *Our customers openly share environmental information with us*
f. *The environmental information shared by participants (suppliers and customers) in our supply chain is available on a real-time basis*

3. *Please select (up to three choices) the main environmental sustainability objectives you intend to pursue through your information system.*

*Options:*

- *Conducting LCA of our products*
- *Eco-design*
- *Reducing the environmental impact of our products*
- *Reducing energy consumption related to our processes and operations*
- *Reducing other environmental impacts related to our processes and operations*
- *Monitoring environmental information, such as resource use, emissions, and waste production*
- *Improving decision-making by executives by highlighting environmental sustainability issues*
- *Limiting carbon and other emissions related to our processes and operations*
- *Supporting the generation and distribution of renewable energy*
- *Other*

4. *Green Product Innovation. For each of the following statements, please indicate your agreement on a 1 to 5 scale, where 1 indicates very low and 5 indicates very high. Products are designed…*
   a. *to reduce resource consumption during production phases*
   b. *to facilitate disassembly, reusability, and recyclability*
   c. *to avoid or reduce the use of hazardous materials*
   d. *to produce less by-products and waste*
   e. *for easy storage and handling during transportation*
   f. *to use less energy during production phases*

---

Regarding the interviews, these were designed to investigate more thoroughly the issues that emerged from the questionnaire findings, together with open-ended questions on specific areas of interest. Naturally, the exact questions varied across interviews, but the most frequently recurring ones are like the ones in the table below.

*Table 1. Main questions asked during the interview*

| Strategy | Questions |
|---|---|
| Compliance with Environmental Regulations | • Do you believe that regulations make it easier to obtain information from your suppliers? |
| Green Information Systems | • Do you use digital tools or platforms to track and manage sustainability data across the supply chain?<br>• How does your information system support sustainable product development? |
| Green Innovation | • Have you developed new products or processes specifically to reduce environmental impact? Are sustainability metrics built into the design phase, or is this still a future goal?<br>• What strategies do you use to encourage suppliers to adopt eco-design practices?<br>• Does having access to supply chain impact data / your information system support you in the development more sustainable products?<br>• Are your customers willing to cover any additional costs for a more sustainable product, or is price still the deciding factor?<br>• Do you believe that greater standardization of sustainability data would promote the development of greener products within your organization? |
| Certifications and Life Cycle Assessment | • Are sustainability certifications or decarbonizing still voluntary for your suppliers? |
| Transparency and Data Sharing | • When do you decide to directly contact Tier 2 suppliers? Does this decision depend on region, industry sector, or other factors?<br>• What are the main challenges in collecting environmental data from suppliers? Do you face resistance from them?<br>• Do you believe that the information suppliers give you is reliable?<br>• How do you ensure the reliability of supplier-provided information?<br>• When you receive sustainability data, is it difficult to interpret or analyse?<br>• Do you conduct audits, or do you rely only on self-reported data?<br>• Do you think some suppliers are deliberately withholding sustainability data, or do they simply lack the maturity and capability to provide it? |
| Integration of Sustainability into Corporate Strategy | • Are the power dynamics surrounding sustainability the same as those governing general business decisions? |

| | |
|---|---|
| | • Do you use sustainability benchmarks? How do you compare against other companies in your sector? |
| Sustainable Supply Chain on the Customer Side | • Between you and your client, who holds more power in imposing sustainability requirements?<br>• Have you ever found sustainability requests from your own suppliers to be unreasonable?<br>• Are you able to refuse certain sustainability requests from clients or partners? |
| Supplier Engagement in ESG Practices | • Do you already involve indirect (Tier 2 or lower) suppliers in sustainability initiatives, or is that still a future goal?<br>• Why do you choose not to involve certain indirect suppliers?<br>• Between you and your client, who holds more power in imposing sustainability requirements?<br>• How do you persuade your suppliers to participate in your sustainability initiatives?<br>• Do you offer incentives, financial or otherwise, to suppliers to encourage them to undertake sustainability measures? Once you impose sustainability standards on your suppliers, do you need to actively follow up, or do they proceed on their own? |
| Sustainability Requirements and Certifications in Contracts | • Do you include contractual clauses mandating the sharing of sustainability data and requirements with your supply chain partners?<br>• Have you ever encountered non-compliance with sustainability clauses in your contracts?<br>• How do you respond when these clauses are violated?<br>• What methods do you use to ensure your suppliers comply with your sustainability requirements?<br>• Which factors influence the power dynamics when imposing sustainability requirements on suppliers? |

## 3.3 Research approach and data analysis techniques

The topics covered in our interviews, encompassing both the sustainability strategies adopted by companies and other relevant areas of interest have been divided into the following themes:

- Compliance with environmental regulations
- Green information systems
- Green innovation
- Certifications and Life Cycle Assessment

- Transparency and data sharing
- Integration of sustainability into corporate strategy
- Sustainable supply chain on the customer side
- Supplier engagement in ESG practices
- Sustainability requirements and certifications in contracts

Through this categorization, the interviews' content has been divided into topics and organized into a spreadsheet. After this initial categorization, more in-depth analyses have been carried out.
For more detailed information, please refer to the tables in the appendix, where the spreadsheets used for the analyses are displayed. In addition to the qualitative analysis of the interviews, an evaluation of the questionnaire responses was conducted. The data collected through the questionnaires were compiled into a separate spreadsheet, where key metrics were calculated to facilitate comparisons with the insights gathered from the interviews, such as averages and frequencies. This allowed for a quantitative assessment of the declared sustainability practices, offering a basis for comparing companies' self-reported data with the qualitative evidence from the interviews. For detailed numerical insights, please refer to the tables in the appendix, where the statistical results from the questionnaire analysis are presented.

# 4. Results of the Analysis

## 4.1 Categories of the analysis

In pursuing sustainability objectives, companies can adopt various strategies, ranging from energy efficiency and the use of renewable energy sources to emissions reduction, recycling, and other circular economy practices. Additionally, social sustainability initiatives play a crucial role, including support for local communities, promotion of diversity and inclusion within the company, and many more. Among the numerous available strategies, this study focuses on those particularly relevant to high-tech companies.

In recent years, increasing public awareness of both environmental and social sustainability has placed companies under growing scrutiny, pushing them to strengthen their commitment in this field. This trend has also led to a stricter regulatory framework, requiring companies to swiftly adapt to ensure compliance and business continuity.

The key sustainability strategies examined in this research focus on three main areas. Sustainable supply chain management, done by focusing on the transparency and data sharing (of the companies with their suppliers), supplier engagement in ESG practices, and the integration of sustainability requirements and certifications into contracts. Secondly, Green Innovation, which involves the development of new technologies and processes aimed at reducing the environmental impact of products, with a particular emphasis on eco-design. Lastly, Green Information Systems as essential tools for managing and analysing sustainability-related data, enabling companies to track their environmental performance and optimize their sustainability initiatives. Beyond these specific strategies, the interviews reveal valuable insights into the challenges companies face when adapting to external sustainability demands, particularly regarding compliance with European regulations and managing customer expectations.

The findings have been categorized to structure the interpretation of the interviews and deepen the analysis of the emerging implications.

These categories are:

- Green information systems
- Green innovation
- Certifications and Life Cycle Assessment
- Compliance with environmental regulations

- *Integration of sustainability into corporate strategy:*
    - Sustainable supply chain on the customer side
    - Integration of sustainability into corporate strategy
- *Sustainable supply chain management:*
    - Transparency and data sharing
    - Supplier engagement in ESG practices
    - Sustainability requirements and certifications in contracts

## 4.2 Themes coverage

A preliminary analysis that can be conducted on these topics is to assess their relative importance across different companies. To this end, a lexical analysis was performed, measuring the number of words dedicated to each theme in the interview transcripts. This approach allows us to identify which topics were given the most attention by company representatives.

Company A

*Table 2. Lexical analysis of the interview with A*

| Theme | N. words |
|---|---|
| Compliance with environmental regulations | 41 |
| Green information systems | 0 |
| Green innovation | 678 |
| Certifications and Life Cycle Assessment | 127 |
| Transparency and data sharing | 158 |
| Integration of sustainability into corporate strategy | 25 |
| Sustainable supply chain on the customer side | 506 |
| Supplier engagement in ESG practices | 203 |
| Sustainability requirements and certifications in contracts | 144 |

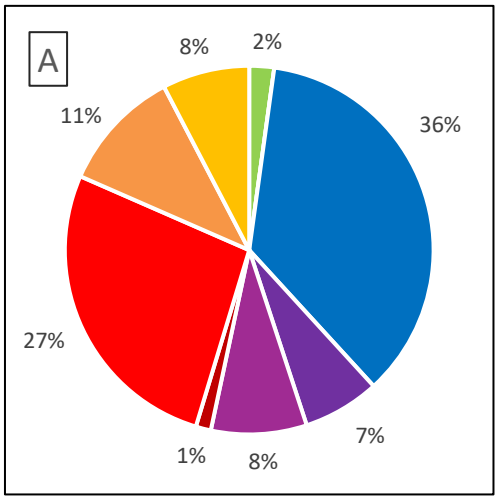


Figure 14. *Percentage distribution of topics discussed in the interview with company A*

Company C

*Table 3. Lexical analysis of the interview with C*

| Theme | N. words |
|---|---|
| Compliance with environmental regulations | 0 |
| Green information systems | 412 |
| Green Innovation | 428 |
| Certifications and Life Cycle Assessment | 235 |
| Transparency and data sharing | 649 |
| Integration of sustainability into corporate strategy | 0 |
| Sustainable supply chain on the customer side | 303 |
| Supplier engagement in ESG practices | 805 |
| Sustainability requirements and certifications in contracts | 95 |

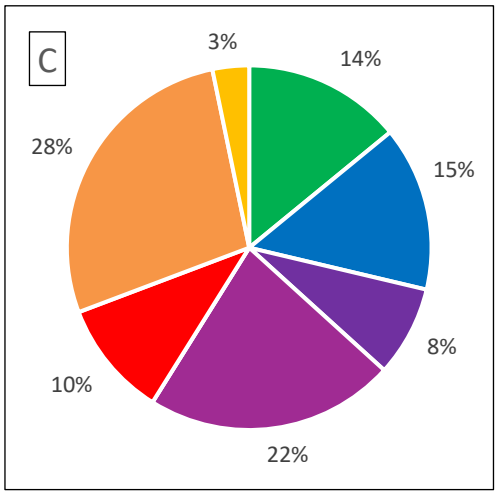


Figure 15. *Percentage distribution of topics discussed in the interview with company C*

Company D

*Table 4. Lexical analysis of the interview with D*

| Theme | N. words |
|---|---|
| Compliance with environmental regulations | 15 |
| Green information systems | 109 |
| Green innovation | 325 |
| Certifications and Life Cycle Assessment | 302 |
| Transparency and data sharing | 696 |
| Integration of sustainability into corporate strategy | 202 |
| Sustainable supply chain on the customer side | 221 |
| Supplier engagement in ESG practices | 652 |
| Sustainability requirements and certifications in contracts | 207 |

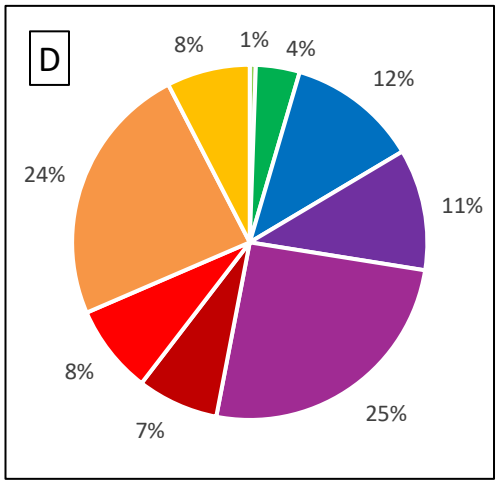


Figure 16. *Percentage distribution of topics discussed in the interview with company D*

Company E

*Table 5. Lexical analysis of the interview with E*

| Theme | N. words |
|---|---|
| Compliance with environmental regulations | 288 |
| Green information systems | 375 |
| Green innovation | 141 |
| Certifications and Life Cycle Assessment | 688 |
| Transparency and data sharing | 910 |
| Integration of sustainability into corporate strategy | 251 |
| Sustainable supply chain on the customer side | 659 |
| Supplier engagement in ESG practices | 1020 |
| Sustainability requirements and certifications in contracts | 277 |

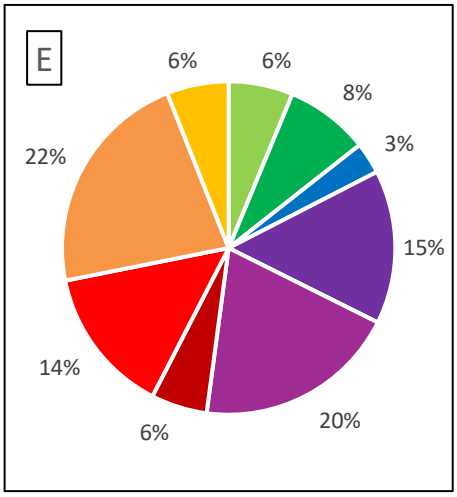


Figure 17. *Percentage distribution of topics discussed in the interview with company E*

Company F

*Table 6. Lexical analysis of the interview with F*

| Theme | N. words |
|---|---|
| Compliance with environmental regulations | 19 |
| Green information systems | 94 |
| Green innovation | 185 |
| Certifications and Life Cycle Assessment | 0 |
| Transparency and data sharing | 163 |
| Integration of sustainability into corporate strategy | 77 |
| Sustainable supply chain on the customer side | 470 |
| Supplier engagement in ESG practices | 348 |
| Sustainability requirements and certifications in contracts | 0 |

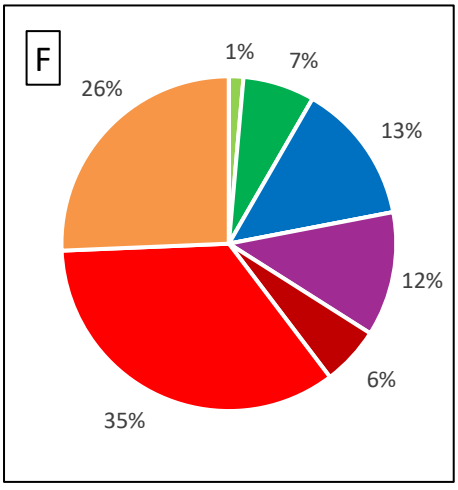


Figure 18. *Percentage distribution of topics discussed in the interview with Company E*

Company H

*Table 7. Lexical analysis of the interview with H*

| Theme | N. words |
|---|---|
| Compliance with environmental regulations | 196 |
| Green information systems | 418 |
| Green innovation | 225 |
| Certifications and Life Cycle Assessment | 200 |
| Transparency and data sharing | 1305 |
| Integration of sustainability into corporate strategy | 198 |
| Sustainable supply chain on the customer side | 42 |
| Supplier engagement in ESG practices | 802 |
| Sustainability requirements and certifications in contracts | 250 |

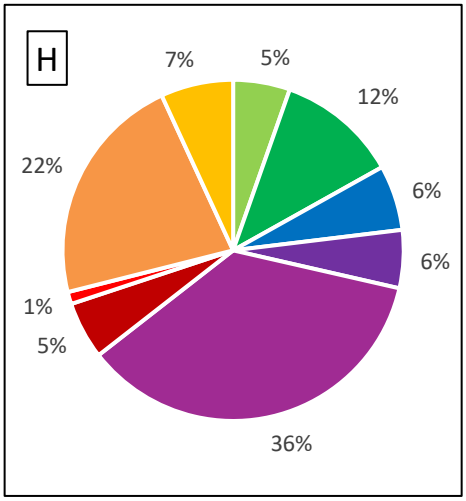


Figure 19. *Percentage distribution of topics discussed in the interview with company H*

Company I

*Table 8. Lexical analysis of the interview with I*

| Theme | N. words |
|---|---|
| Compliance with environmental regulations | 0 |
| Green information systems | 478 |
| Green innovation | 349 |
| Certifications and Life Cycle Assessment | 0 |
| Transparency and data sharing | 995 |
| Integration of sustainability into corporate strategy | 110 |
| Sustainable supply chain on the customer side | 576 |
| Supplier engagement in ESG practices | 790 |
| Sustainability requirements and certifications in contracts | 350 |

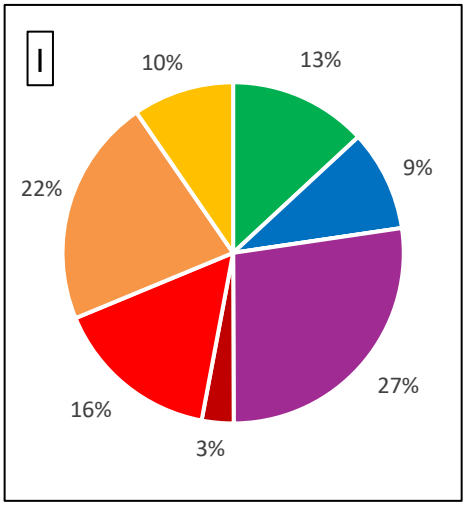


Figure 20. *Percentage distribution of topics discussed in the interview with company I*

## 4.3 Results of the questionnaires

Questionnaires questions primarily focus on Green Information Systems and their implementation, offering interesting insight into these instruments. The specific questions asked can be seen in the *Methodology* chapter.

### 4.3.1 Green Information System adoption within the organization

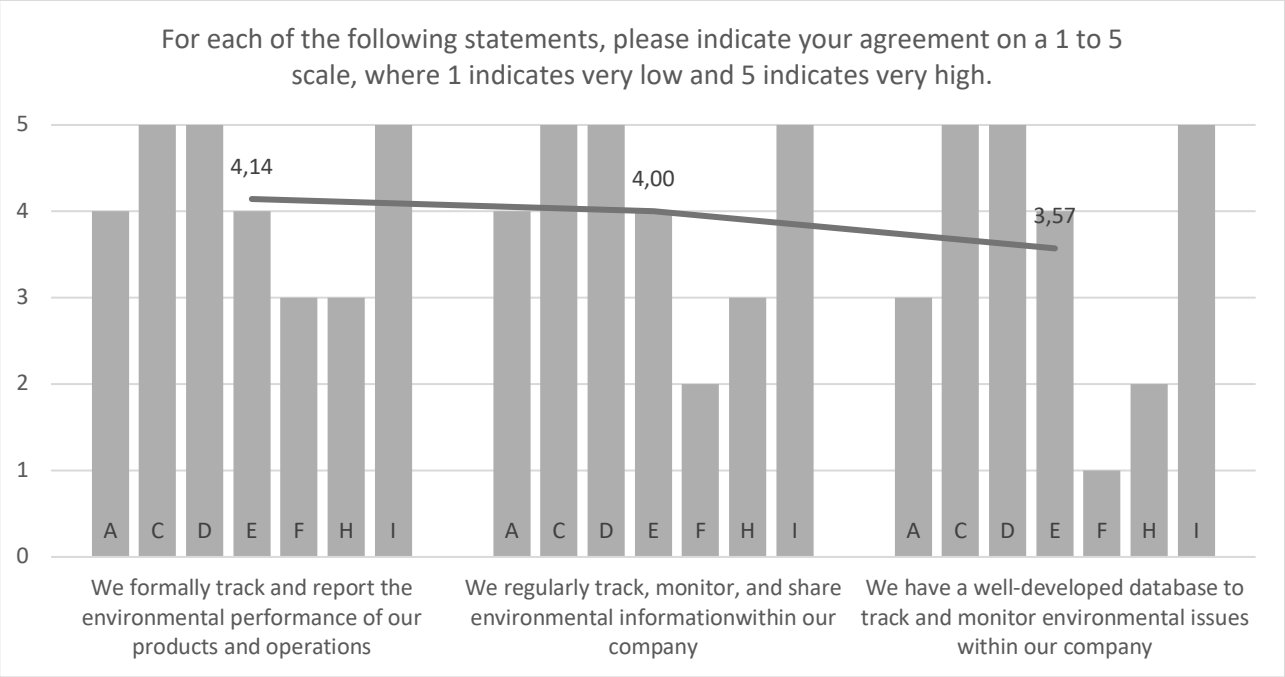


*Figure 21. Green Information System adoption within the organization: companies' responses*

Companies were asked about the existence of a Green Information System and an internal database to manage environmental information. The results show that all respondents regularly track and report environmental data, as evidenced by the statement “We formally track and report the environmental performance of our products and operations” receiving a score higher than 3 from every company. Indeed, three companies rated it as 5. Regarding the sharing of such information, all but one company report being able to do so, each awarding a score above 3 on the statement “We regularly track, monitor, and share environmental information within our company.” Finally, when asked about the presence of a well-developed database for tracking and monitoring environmental issues (via the statement “We have a well-developed database to track and monitor environmental issues within our company”), three companies gave a score of 5, one scored 4, one scored 3, one scored 2, and one scored 1. This indicates that while some organizations have sophisticated databases, others still lag in terms of comprehensive data management systems.

### 4.3.2 Sustainability objectives

*Table 9. Sustainability objectives in using information systems: companies' response*

| **Please select the main environmental sustainability objectives you intend to pursue through your information system** | A | C | D | E | F | H | I |
|---|---|---|---|---|---|---|---|
| Conducting LCA of our products | | | X | X | X | X | X |
| Eco-design | X | X | X | X | | | |
| Reducing the environmental impact of our products | X | | X | X | X | X | |
| Reducing energy consumption related to our processes and operations | | | | X | | | |
| Reducing other environmental impacts related to our processes and operations | | | | X | | | |
| Monitoring environmental information, such as resource use, emissions, and waste production | | X | | X | | X | |
| Improving decision making by executives by highlighting environmental sustainability issues | | X | | X | | | |
| Limiting carbon and other emissions related to our processes and operations | X | | | X | X | X | |
| Supporting the generation and distribution of renewable energy | | | | X | | | |
| Other | | | | | | | X* |

*Regulatory disclosure requirements

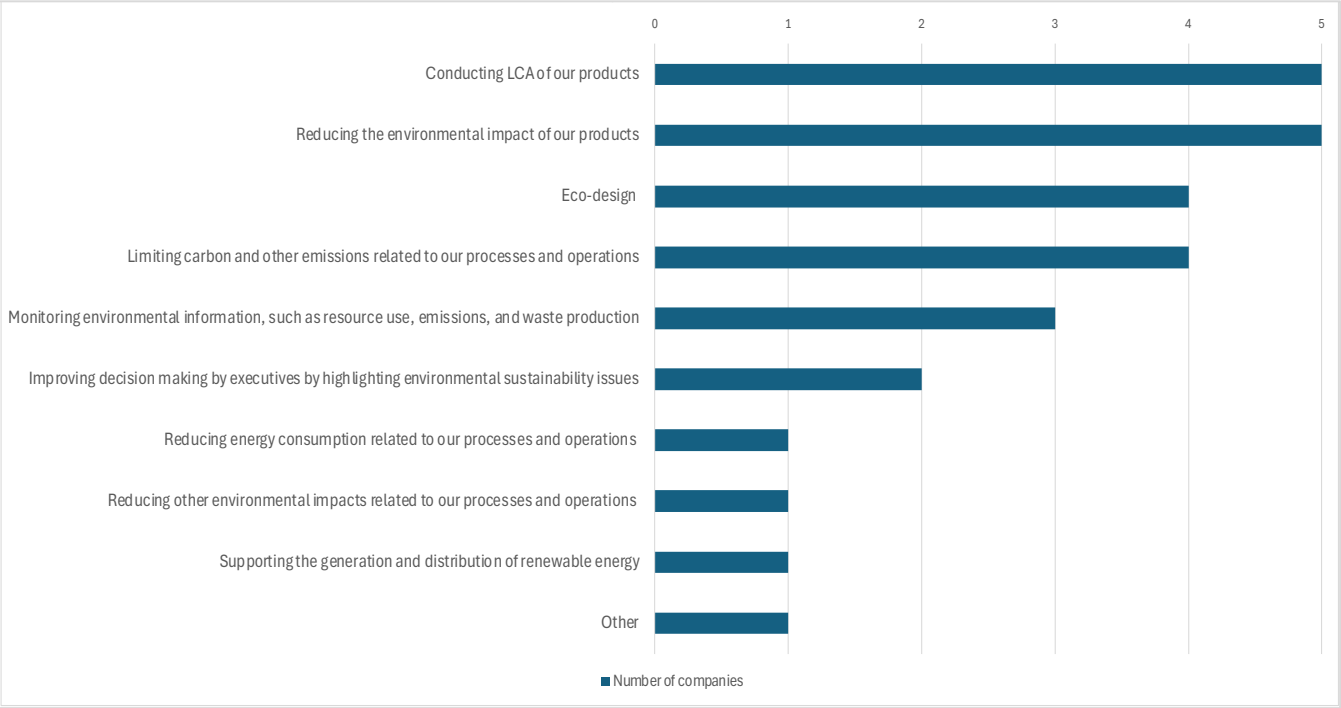


Figure 22. *Sustainability objectives: most common responses*

Subsequently, the companies were asked which sustainability objectives they pursue through their information systems. The most common uses - cited by five out of seven companies - are conducting Life Cycle Assessments of their products and reducing the environmental impact of their products. Four out of seven also reported using their information systems for eco-design and for limiting carbon and other emissions related to processes and operations. Additionally, three companies use them for monitoring environmental information, such as resource use, emissions, and waste production, while two reported improving executive decision-making by highlighting environmental sustainability issues. Only one company each cited reducing energy consumption related to processes and operations, reducing other environmental impacts related to processes and operations, supporting the generation and distribution of renewable energy, and regulatory disclosure requirements as key objectives.

### 4.3.3 Green Information System adoption within the supply chain

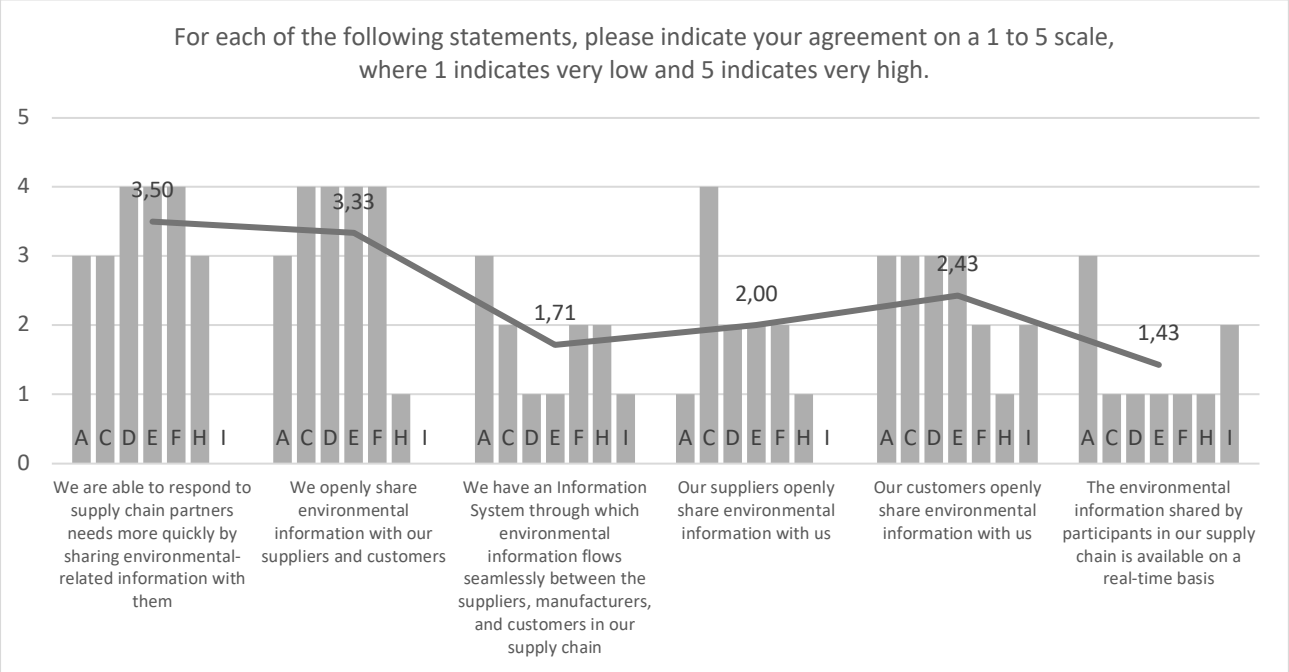


Figure 23. *Green Information System adoption within the Supply Chain: companies' response*

Subsequently, the companies were asked about information sharing within the supply chain. Most of them assign high importance to the ability to respond to supply chain needs by sharing information, as evidenced by every company giving a score of 3 or higher on this statement. Moreover, nearly all report that they "openly share environmental information with our suppliers and customers," with four awarding scores of 4, one a 3, and only one a 1. However, this openness

does not seem to extend fully in the other direction. In response to the statement “Our suppliers openly share environmental information with us,” three companies gave a score of 2, one a 4, and two only a 1. The situation is somewhat better when it comes to information sharing by customers: for the statement “Our customers openly share environmental information with us,” the majority gave a 3, two gave a 2, and just one awarded a 1. As for the system used to facilitate this sharing, the statement “We have an Information System through which environmental information flows seamlessly between the suppliers, manufacturers, and customers in our supply chain” received three scores of 1, three scores of 2, and only one score of 3—suggesting that many organizations have not fully integrated or developed their technology platforms for seamless data exchange. Finally, regarding the speed of sharing, none of the respondents appear to have real-time information on their supply chain’s environmental data. This is reflected in the statement “The environmental information shared by participants in our supply chain is available on a real-time basis,” where five companies gave a 1, one awarded a 2, and only one a 3.

### 4.3.4 Green Product Innovation

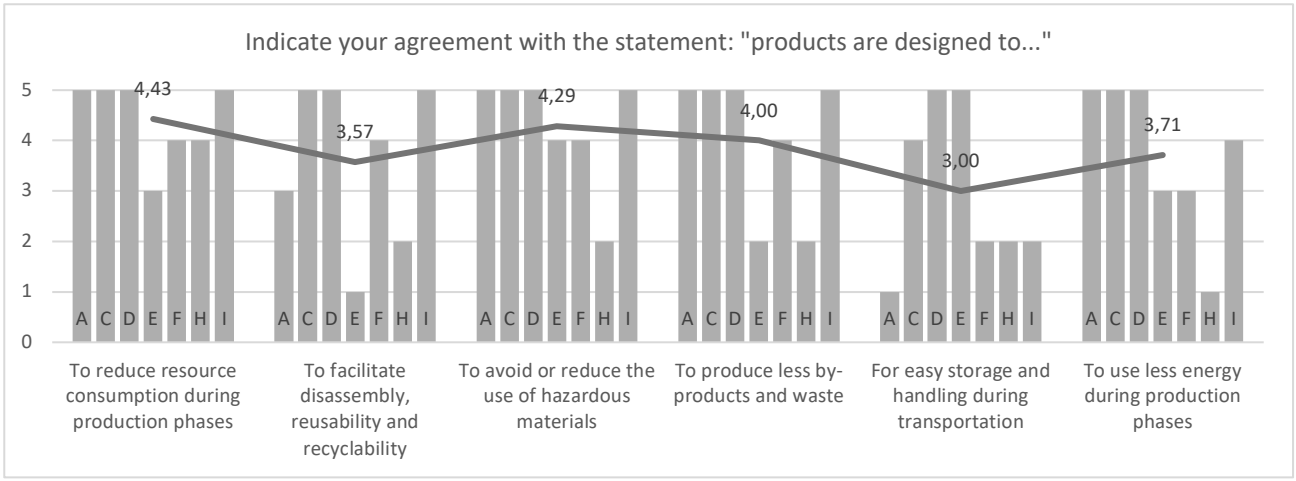


*Figure 24. Green Product Innovation: companies’ responses*

When it comes to product design, the results show that most companies highly prioritize reducing resource consumption during the production phase: four out of seven awarded the statement a score of 5, two gave it a 4, and one a 3. A similarly strong focus emerges regarding the use of hazardous materials—four companies gave a 5 to avoiding or reducing such materials, two gave a 4, and one a 2. End-of-life considerations also appear to be a key concern. On the statement “to produce fewer by-products and waste,” four companies gave it a 5, one a 4, and two a 2. Likewise, “to facilitate disassembly, reusability, and recyclability” received three scores of 5, one 4, one 3, and

one 2, indicating a recurring interest in designing for circularity. Although not as highly rated overall, “to use less energy during production phases” still scored relatively well on average, suggesting that most companies see energy efficiency as an integral aspect of green innovation. Meanwhile, “for easy storage and handling during transportation” received a moderate average score, reflecting a somewhat lower but still notable level of interest.

# 5. Sustainability strategies in the companies analysed

Through the interviews, it was possible to gain more details regarding the practical actions and established methodologies that companies have used to pursue their sustainability objectives.

## 5.1 Green information systems

*Table 10. Sustainability strategies in the companies analysed – Green information systems*

| Company | Details |
|---|---|
| **A** | \ |
| **C** | Use of Eco Vadis to collect secondary data for EPD and primary data for eco-design: Monitoring $CO_2$ emissions, energy consumption, waste management, and water usage from Tier 1 suppliers |
| **D** | Employs Integrity Next to assess ESG risk across the supply chain, screening suppliers for potential sustainability issues |
| **E** | They are about to implement Eco Vadis for monitoring suppliers, as many are already present on the platform. Internally, they have a system that enables real-time carbon footprint calculation during product development |
| **F** | Lacks digital tools to track supplier sustainability performance. They are developing a tool to track suppliers, but it is still in the testing stage |
| **H** | Data is collected through the We Buy purchasing portal, but it is not fully optimized. A new system is currently under development to improve supply-chain data management |
| **I** | "I" is developing an advanced system for collecting environmental data, but it is currently limited. They aim to create a system that captures real-time data from the supply chain. They have a large amount of data, but it is based on statistics, secondary data, and audits, not primary data, and it is not yet integrated into all business processes. As a result, they are still unable to use it for eco-design or impactful decision-making. With significant effort, they can use it only for specific decisions. They collaborate with Aussie Green: data is aggregated and certified via blockchain for Carbon Footprint calculations |

A key element for the success of a sustainability strategy is an effective data collection and management system, which, in the case of environmental data, is referred to as a Green Information System (Green IS). These systems allow companies to monitor the supply chain when managing external data or to perform real-time Life Cycle Assessments (LCA) and Eco-design when tracking internal data. Most companies have implemented some form of Green IS, though with varying levels of development and integration. The use of external tools is widespread, particularly for supply

chain monitoring, with platforms like Eco Vadis and Integrity Next used to assess ESG risks and supplier performance. Some procurement platforms, such as We Buy, also can facilitate data collection, though optimization remains an ongoing process. For internal sustainability data management, companies tend to develop in-house solutions. These systems are often still under development. Advanced technologies such as blockchain are being explored to enhance data transparency and certification, particularly in areas like carbon footprint calculations.

## 5.2. Sustainable supply chain management

The sustainable management of the supply chain is divided into three areas: Transparency and Data Sharing, Supplier Engagement in ESG Practices, and Sustainability Requirements and Certifications in Contracts. These capture the main levers companies use to manage sustainability within their supply chains. *Transparency and Data Sharing* focus on why and how companies collect, track and communicate environmental and social information and how they verify and audit information coming from their suppliers. *Supplier Engagement in ESG Practices* highlights the ways firms collaborate with and motivate suppliers to adopt more sustainable behaviours, whether through training, incentives, or strategic partnerships. Finally, *Sustainability Requirements and Certifications in Contracts* emphasize how sustainability expectations are formally defined, enforced, and verified through procurement clauses and standards.

*Table 11. Sustainability strategies in the companies analysed – supplier engagement in ESG practices*

| Company | Details |
|---|---|
| **A** | Tier 1 suppliers are involved only to a limited extent and mainly upon customer request, given that the supply chain is predominantly based in China and due to regional characteristics and differing ESG standards, supplier engagement is challenging |
| **C** | "C" manages to influence on Tier 1 suppliers to procure more sustainable materials, with an indirect impact on Tier 2 suppliers. It also gives support for suppliers in emission calculations and internal process optimization |
| **D** | For new suppliers, the company immediately enforces compliance with ESG procedures, requiring adherence to the Supplier Code of Conduct and using Integrity Next for self-assessment of sustainability practices. For existing suppliers, D applies the same Integrity Next screening to identify potential ESG risks. Based on the results, it prioritizes ESG audits for suppliers with higher risk levels. Additionally, D uses a scorecard system to monitor supplier compliance with sustainability requirements, assigning them a rating and implementing corrective actions when necessary, supporting them in improving their ESG performance |

| | |
|---|---|
| **E** | “E” seeks to leverage initial openings on sustainability topics with Chinese suppliers, encouraging them to take even small actions such as purchasing renewable energy certificates. It uses regulations to obtain certifications for satisfy customers’ requests. To strengthen monitoring, the company plans to adopt EcoVadis, which will provide an ESG scorecard for suppliers. However, it will not be possible to exclude suppliers with low scores (red category) directly, so the strategy will focus on engagement initiatives to improve ESG performance without compromising operational continuity |
| **F** | Supplier evaluation is based on an ESG questionnaire via EcoVadis, which assigns scores and identifies risks. The company works with suppliers to understand why these risks exist. If the score is too low or fundamental parameters are not met, the supplier is excluded |
| **H** | “H” aims to reward more sustainable suppliers. To incentivize suppliers to adopt more sustainable practices, it has introduced "sustainability levers," which provide advantages in bidding processes to those engaging in sustainable actions, such as obtaining environmental certifications or adopting sustainability policies. Some of these requirements also impact Tier 2+ suppliers, especially in high-risk raw material supply chains such as lithium, aluminium, and copper, where supply chain traceability is required. Additionally, suppliers are required to complete self-assessments and sustainability scorecards, with requests cascading from H's direct suppliers to the lower levels of the supply chain |
| **I** | “I” provides financial and non-financial incentives to Tier 1 suppliers to improve their sustainability performance. Currently, some requirements, such as signing the Code of Conduct, are already mandatory for all suppliers, while others vary depending on the raw material or sector. The company has launched a pilot study to collect emissions data and increase transparency on decarbonization efforts, involving Tier 1 and, in some cases, Tier 2 suppliers in high-impact sectors ("hotspots"). This study also aims to develop penalty mechanisms for suppliers that do not meet sustainability standards. Although the company actively encourages suppliers to promote sustainable practices along the value chain, most direct actions, such as formal audits and incentives, are limited to Tier 1 suppliers. This is because, because the company believe that in its industries, such as electronics, processes are already highly standardized, and suppliers already oversee their sub-suppliers sufficiently. However, “I” requires Tier 1 suppliers to engage lower-tier suppliers and, in high-risk cases, directly interacts with Tier 2, assessing the need for intervention based on factors such as region and supply type |

The involvement of suppliers in ESG practices includes information sharing (which will be covered in more detail in the next section), as well as supplier evaluation and the influence that companies exert in enforcing sustainability requirements and actions. A common method is signing a Code of Conduct, which is mandatory for suppliers in some companies, and conducting assessments through tools such as Eco Vadis and Integrity Next. These platforms provide ESG ratings, risk assessments, and scorecards to help monitor supplier performance, other than collecting information from them. In some cases, such evaluations help companies determine whether a supplier can continue the

collaboration. In other cases, they use these assessments to prioritize audits and invite them to take corrective actions where necessary. Another engagement strategy is the use of sustainability incentives in procurement processes, like giving advantages in bidding processes to those who adopt ESG certifications or policies. Engagement beyond Tier 1 and with Chinese suppliers remains a challenge. Some companies manage to indirectly influence Tier 2 suppliers by working through their Tier 1 partners. Similarly, there is a case of a company influencing Chinese suppliers to take small steps, such as purchasing renewable energy certificates.

*Table 12. Sustainability strategies in the companies analysed – Transparency and data sharing*

| Company | Details |
|---|---|
| **A** | A collects data from suppliers to satisfy costumers' request. Faces difficulties in gathering environmental data, especially from small suppliers lacking measurement tools |
| **C** | Data collection with Eco Vadis for approximately 150-200 Tier 1 suppliers, with detailed data on carbon emissions. Occasional involvement of Tier 2 suppliers, with responses varying depending on availability and collaboration. Planned sample audits to verify the quality of environmental data provided by suppliers |
| **D** | Conducts supplier due diligence only for Tier 1 suppliers. Integrity Next is used for auditing |
| **E** | The company is unable to conduct direct audits, so it relies on the data obtained through ESG assessments through tools like Eco Vadis or Achilles to quantitatively analyse Tier 2 suppliers (producers), while the evaluation of Tier 1 suppliers (distributors) is qualitative. Tier 3 suppliers (raw material providers) are not assessed, except in areas covered by regulatory standards, such as conflict materials, where secondary data is used. The company also uses sustainability reports to obtain certified data without having to request information directly from suppliers, particularly when they are unwilling to provide it. |
| **F** | Data from suppliers is collected through questionnaires. No mentions of any structured approach or data updates |
| **H** | The company focuses on mapping the supply chain, concentrating on Tier 1 suppliers and, among Tier 2 suppliers, only those considered high risk. This is because of the technical complexity of its products. Every new supplier must pass a qualification process, which includes registration on a procurement portal, where environmental, safety, human rights, and technical aspects are assessed. In some critical sectors subcontractors are also required to complete the registration and qualification process.<br>For selected products, the company collects details on the origin of materials, through “material passport”, documents detailing raw materials and product components. However, they are primarily based on self-declarations, which can be difficult to verify.<br>The verification of the sustainability assessments provided by suppliers is done manually by sustainability representatives without the support of automated tools or third-party auditing |

| | |
|---|---|
| **I** | Collects data directly from Tier 1 suppliers and invites them to do the same. It is developing AI/Machine Learning techniques to improve transparency. It uses third-party audits in higher-risk sectors for Tier 2. They collaborate with Aussie Green: data is aggregated and certified via blockchain for Carbon Footprint calculations |

The collection of data from suppliers is a fundamental element of sustainable supply chain management, as well as a regulatory requirement, which is why all companies have implemented practices for this purpose. In general, data collection is more structured for Tier 1 suppliers, while access to information from Tier 2 and Tier 3 suppliers is more limited and often depends on the collaboration of the suppliers themselves. The strategies adopted by companies to collect and verify data vary some rely on ESG rating platforms such as Eco Vadis, Achilles, and Integrity Next, while others use proprietary tools or manual processes to analyse and verify the data. An interesting development is the use of advanced technologies such as Artificial Intelligence and Machine Learning, which one company is developing to enhance real-time transparency and traceability in the supply chain, or Blockchain technologies to certify the data shared. One method that some companies highlight for obtaining information is the use of sustainability reports as a source of data, particularly useful when suppliers are reluctant to share information. Finally, the verification of the quality of collected data remains an area with little structure in many companies: some rely on third-party audits, while others conduct manual internal checks.

*Table 13. Sustainability strategies in the companies analysed – Sustainability requirements and certifications in contracts*

| Company | Details |
|---|---|
| **A** | \ |
| **C** | Possible contractualization of sustainability requests for suppliers, in addition to current regulatory requirements (code of conduct, anti-corruption, child labor), despite regulatory complexity |
| **D** | Suppliers they work with must confirm adherence to the Supplier Code of Conduct, which includes an appendix called Green Procurement Requirements. This specifies the required environmental expectations, such as compliance with regulations like RoHS and REACH and the provision of environmental data, including GHG emissions |
| **E** | The company uses General Purchasing Conditions (GPC) as sustainability contractual requirements. These include signing the code of conduct and complying with mandatory regulations (REACH and RoHS). Certifications such as ISO 14001 and full material declaration are preferred but not essential |

| | |
|---|---|
| **F** | New suppliers must complete an ESG questionnaire and meet standards; negative responses lead to exclusion. Other than this initial requirement, no mention of ongoing sustainability enforcement through contracts |
| **H** | The company integrates binding sustainability clauses into contracts, imposing environmental certification requirements and incentive criteria (sustainability K) to encourage suppliers to adopt more sustainable practices. To ensure compliance, Tier 1 suppliers must sign the company's Code of Conduct, while Tier 2 suppliers must ensure compatibility between their own code and the company's. Contracts include specific sustainability commitments, such as requiring suppliers to provide environmental certifications and share information about their sustainability practices. Compliance with these obligations is verified through the procurement portal, where suppliers must provide data on environmental, safety, human rights, and technical aspects. However, the company does not have a system for direct verification of this information. There are penalties for not compliance |
| **I** | "Ready for Business Requirements" include sustainability aspects, defined as "non-contractual" because they are non-negotiable. These are mandatory conditions to initiate business relationships with the company. In addition to sustainability, these requirements also include data sharing but do not focus exclusively on environmental metrics. Currently, sustainability requirements imposed on suppliers do not include formal escalation measures, but they are expected to become binding in the future |

Companies can take on a quasi-regulatory role, imposing sustainability standards on other actors within the supply chain, when they have the power to do so. In general, all legally required aspects are contractually enforced in the countries where the company operates. However, some companies go beyond regulatory compliance, aiming to anticipate future regulations or demand higher sustainability standards. Sustainability requirements are often incorporated into codes of conduct, general purchasing conditions, or procurement policies. Approaches to enforcement vary. In some cases, sustainability criteria become contractual obligations, with compliance monitored through audits or third-party and companies integrate penalty mechanisms for non-compliance, while others use incentives to reward sustainable practices rather than imposing strict mandates.

## 5.3 Green Innovation

*Table 14. Sustainability strategies in the companies analysed – Green innovation*

| Company | Details |
|---|---|
| **A** | Upon customer request (project trade), more sustainable products are developed. However, this is not yet done for all products. There are difficulties in using recycled materials as raw materials, as they produce electronic products whose characteristics must be well-defined, which cannot always be guaranteed |

| | |
|---|---|
| **C** | In a transition phase towards the implementation of eco-design, it does pilots project to collect primary data and conduct comparative analyses on materials and product solutions |
| **D** | The data collection system is not yet advanced enough to support green innovation, so for now, it is only used for disclosure purposes. However, D aims to use it to develop greener products |
| **E** | The company has an information system for carbon footprint analysis, which now includes both the electronic and mechanical parts of the BOM. This allows real-time calculation of a product's environmental impact during its development phases and prioritizes suppliers with better environmental performance. Eco-design will not be applied to all products but only to those where the added value of a lower environmental impact is recognized |
| **F** | Green innovation is driven by customer requests, regulations, and economic considerations. The company does not automatically adopt sustainable materials by its own initiative |
| **H** | As a commercial company, H does not engage in product design. However, in the markets where it is strongest (for intellectual property and know-how), it manages to influence suppliers to develop more sustainable products. |
| **I** | They recognize the importance of eco-design for decarbonization but face challenges due to the lack of primary data from Tier 3–4 suppliers. They aim to develop a system for real-time eco-design and are working on bridging data gaps through a "Green Digital Twin". It is developing AI/Machine Learning techniques to improve transparency. It uses third-party audits in higher-risk sectors for Tier 2. They collaborate with Aussie Green: data is aggregated and certified via blockchain for Carbon Footprint calculations |

Green Innovation refers to the development and implementation of new technologies, processes, products, or business practices that reduce environmental impact and improve resource efficiency. In this thesis, eco-design is also considered a form of Green Innovation, as it integrates sustainability principles into product design. Most companies engage in some form of Green Innovation, either proactively or in response to customer and market demands. However, the extent to which eco-design and green innovation are applied varies. A critical enabler of Green Innovation is the availability of environmental and material consumption data. Companies that have advanced data collection systems can better integrate sustainability into their product development processes. Some companies prioritize pilot projects to experiment with new materials and comparative analyses, while others develop internal information systems that enable real-time emissions calculations to support eco-design decisions. Regarding innovative technologies, in addition to the already mentioned AI/Machine Learning and blockchain to enhance transparency, the same company is also developing "green digital twins" to enable eco-design even in the absence of primary data.

## 5.4 Other sustainability strategies

*Table 15. Sustainability strategies in the companies analysed – Certifications and Life Cycle Assessment (LCA)*

| Company | Details |
|---|---|
| **A** | They perform EPD certifications upon customer request |
| **C** | They carry out two types of LCA: one for EPD (using secondary data, which is preferred by certification bodies) and one for eco-design (using primary data). Nearly half of the product portfolio is covered by EPD |
| **D** | Carries out LCA upon customer request rather than as a standard practice |
| **E** | They calculate product carbon footprints in real time as the product is developed. LCAs are performed quickly upon customer request. Many supplier data are gathered from sustainability reports |
| **F** | LCA is not yet systematically conducted LCA for all products, even though they see its potential value |
| **H** | They created the a certification, that partially helps verify and certify the amount of recycled material contained in their products. LCAs are not mentioned |
| **I** | *(not mentioned)* |

Certifications are an essential tool for demonstrating sustainability efforts, ensuring that commitments in this area translate into added value for the product or help meet customer requirements. The most common certifications - based on the interviews - are Life Cycle Assessment (LCA) and Environmental Product Declarations (EPD). These assessments are sometimes conducted proactively as part of an internal sustainability strategy, while in other cases, they are carried out in response to market demands. LCAs also play a crucial role in the development of sustainable products, both within the company itself and for its customers. Some companies use LCAs primarily for EPD certifications, relying on secondary data as preferred by certification bodies, while others integrate LCAs into their eco-design processes. Others perform LCA analyses only upon request and have not yet implemented them as a systematic practice across all products.

*Table 16. Sustainability strategies in the companies analysed – Client-focused sustainability strategy*

| Company | Details |
|---|---|
| **A** | They commit to meeting the sustainability requirements requested of them, with verifications carried out by the quality department. If the client requests it, the company must provide a more sustainable product, but product quality remains the top priority over decarbonization. |

| | |
|---|---|
| | Sometimes, they request a higher price for a sustainable alternative, and sometimes they do not accept it |
| **C** | Responsiveness to client sustainability requests, with strategies evolving based on their needs. Anticipating market sustainability demands to remain competitive compared to competitors |
| **D** | They consider it essential to meet client requests |
| **E** | If a client requests the carbon footprint, it is quickly calculated (within two weeks) to build client loyalty, making the process valuable for them. The same request is likely asked of multiple people, ensuring efficiency. When an LCA is requested, they are ready to carry it out in a thorough and meticulous manner |
| **F** | The company's responses to clients vary depending on the client's size and impact on the company. If the client is large, they try to act immediately. If the client is small, the request may be postponed to the following year or not fulfilled if it is not considered impactful or useful to the company. In general, they aim to respond to client requests based on how they align with the company's ESG strategy |
| **H** | *(not mentioned)* |
| **I** | They strive to satisfy the client. The only requests that are not met are the ones perceived as unrealistic. Client questionnaires: The company tries to standardize and provide generic responses to client survey requests due to their complexity, as they receive many from different countries. In some cases, clients are not satisfied with standard responses and make specific requests, which are often difficult to understand or fulfil |

The impact of sustainability requirements imposed by clients can be observed in how companies respond to them. Across all companies, there is a strong willingness to meet client and market demands, as well as to align with competitors' offerings, particularly regarding sustainability aspects. Some companies fully commit to meeting any sustainability requirement to the best of their ability, viewing it as a core business objective or competitive advantage. These companies prioritize quick, high-quality certification processes to strengthen client relationships and maintain market position. Others negotiate sustainability requests or seek compensation for additional efforts. In certain cases, companies prioritize larger clients, addressing their sustainability needs more promptly, while requests from smaller clients may be postponed or rejected based on perceived business impact. Additionally, some companies standardize responses to sustainability questionnaires to manage the complexity of multiple requests from different markets.

# 6. Challenges and barriers to the implementation of sustainability strategies

## 6.1 Challenges and obstacles identified

Through the interviews, it was possible to more precisely identify the challenges companies face when implementing their sustainability strategies. Additionally, various obstacles arise from having to meet external demands, both regulatory and customer-driven, that must be addressed to remain competitive in the market. Recognizing these difficulties is essential for understanding the maturity of these strategies, as well as the forces that drive or hinder their progress. For this reason, the following chapter is focused on analysing these issues, which are summarized in the graphs below.

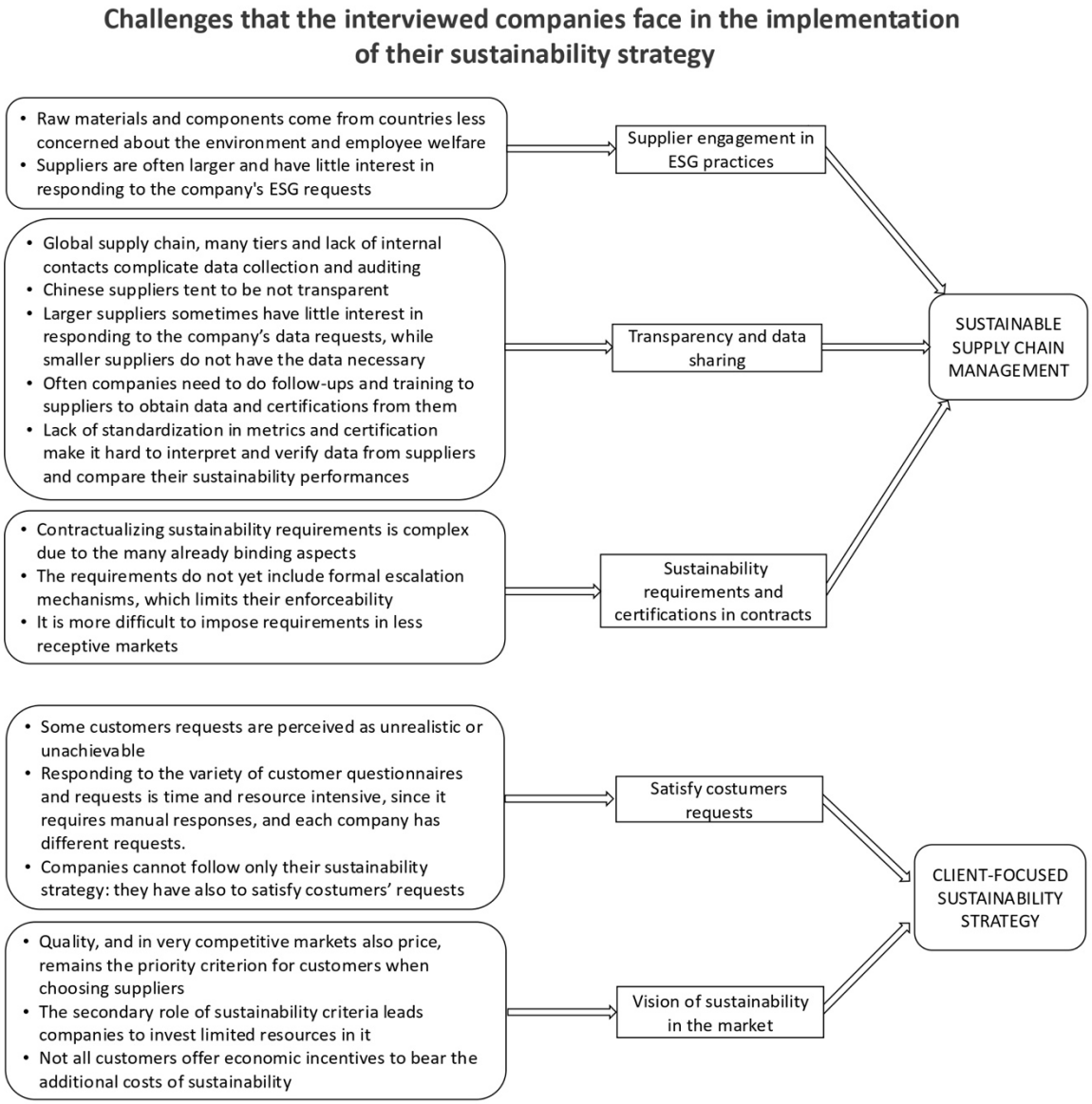


*Figure 25. Challenges and barriers to the implementation of sustainability strategies – 1 – Source: Author's elaboration*

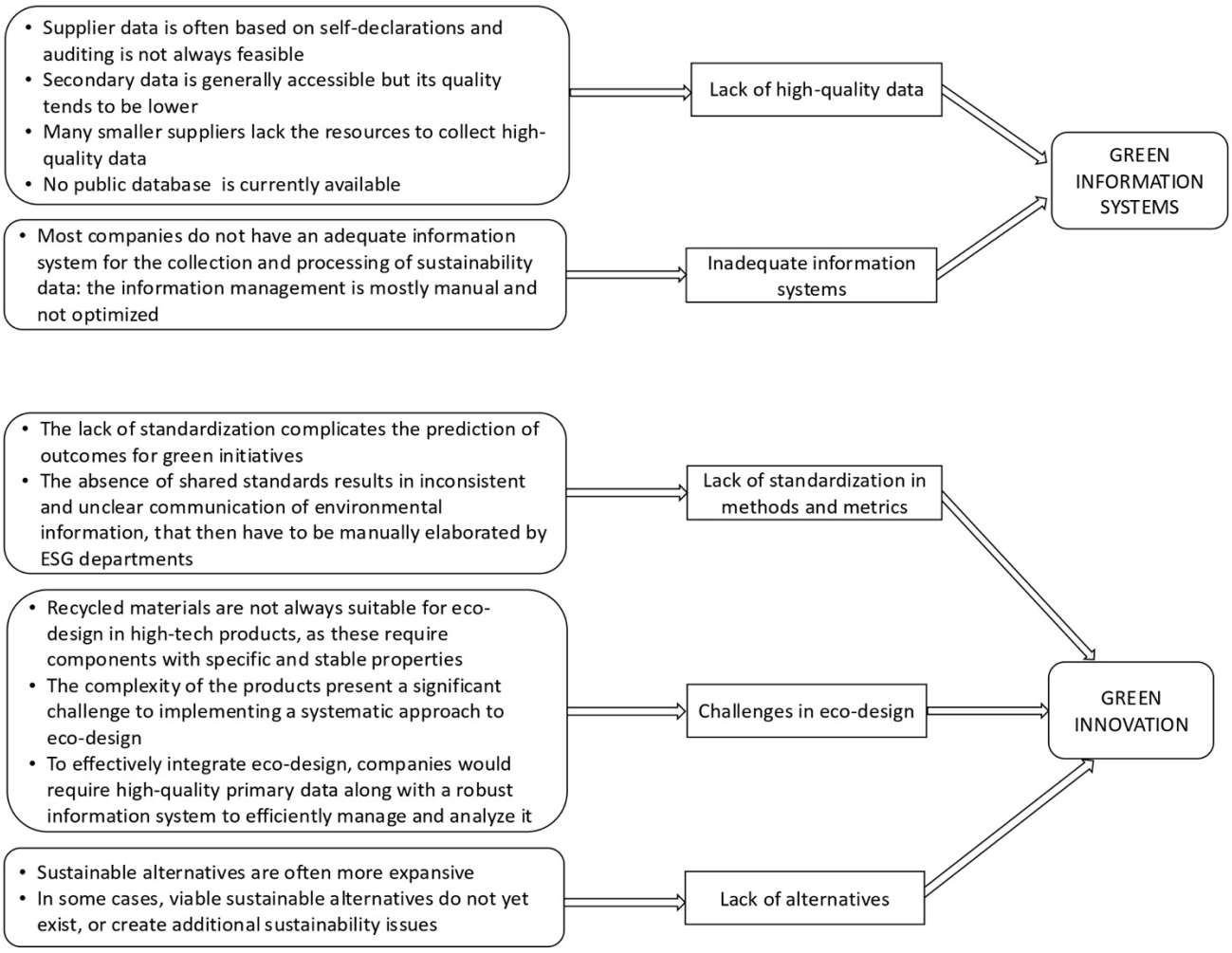


*Figure 26. Challenges and barriers to the implementation of sustainability strategies – 2 – Source: Author's elaboration*

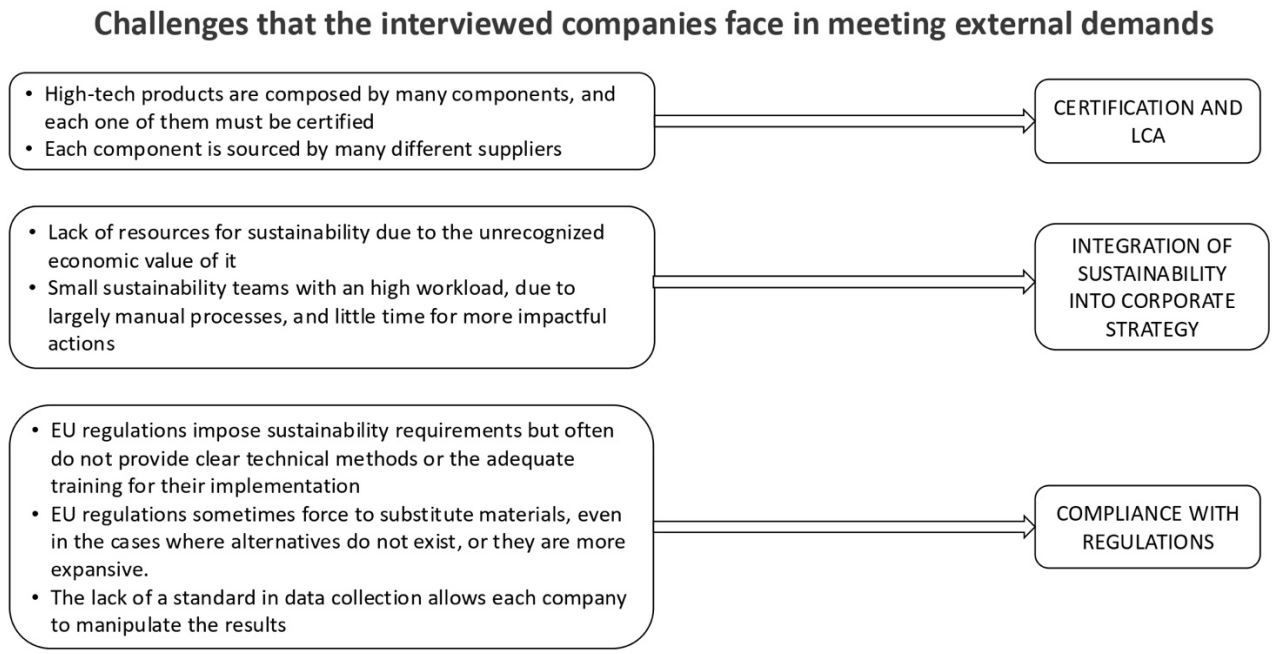


*Figure 27. Challenges and barriers to the implementation of sustainability strategies – 3 – Source: Author's elaboration*

## 6.2 Challenges and obstacles faced for each strategy

In the analysis of the interviews, along with the strategies employed by companies, it is also possible to identify the challenges they encounter in implementing them. Many of these challenges are recurrent among different companies, highlighting common obstacles and offering valuable insights into the most critical barriers. Some difficulties arise from external factors, such as regulatory complexity or supplier resistance, while others pertain to internal limitations, such as a lack of adequate digital tools or dedicated resources. Examining these obstacles enhances our understanding of not only the effectiveness of the strategies adopted but also potential areas for improvement.

### *6.2.1 Green information systems*

*Table 17. Challenges and obstacles faced in green information systems*

| Company | Sub-theme | Details |
|---|---|---|
| **C** | Data quality | Obtaining high-quality primary data for all products is challenging due to their complexity and the large number of components. As a result, the company relies on secondary data, which is of lower quality. |
| **D - I** | Data quality | Many companies lack robust real-time data collection systems, resulting in low-quality data being provided, based on statistical data. |
| **H** | Data quality | There are difficulties in verifying the quality and accuracy of the provided information, as it is often self-reported. |
| **I** | Data quality | Sometimes suppliers provide questionable data, such as unreliable claims about "net zero" pathways. |
| **F** | Inadequate information systems | The tool for supplier analysis is still in an early phase and has been tested on a limited number of suppliers. As a result, the work is highly manual and not optimized. |
| **H** | Inadequate information systems | The company uses a supplier data collection system that is not suitable (procurement portal). |

### *6.2.2 Sustainable supply chain management*

*Table 18. Challenges and obstacles faced in supplier engagement in ESG practices*

| Company | Sub-theme | Description |
|---|---|---|
| **D** | Issues with Asian suppliers | Suppliers based in Asia, for example, often operate with misaligned ESG standards and communication practices. |

| | | |
|---|---|---|
| **D – H – I** | Lack of standardization | The absence of standardization in measurement units and measuring process for certifications and reports makes it difficult to select the best supplier, particularly in terms of emissions reduction. |
| **C – D – E** | Limited influence on suppliers | Suppliers, especially T2, with large global suppliers for whom it represents a marginal client, making it difficult to exert influence. |
| **H** | Supply chain complexity | There are too many suppliers to conduct assessments on all of them. |
| **C** | Complex supplier engagement | The company must invest significant resources in follow-ups and support. |

*Table 19. Challenges and obstacles faced in transparency and data sharing*

| Company | Sub-theme | Description |
|---|---|---|
| **D** | Complex supply chain | A global supply chain, multiple tiers, and a lack of internal contacts complicate data collection. Often, the company is unable to reach the right person to obtain the necessary data. |
| **A - C** | Difficulty obtaining data from suppliers for the lack of it | Collecting data is generally difficult, especially from small producers who struggle to obtain it. |
| **E** | Difficulty obtaining data from suppliers for the lack of it | Tier 1 suppliers are distributors who lack information |
| **I** | Difficulty obtaining data from suppliers for unwillingness of sharing | Many suppliers resist sharing information due to a lack of expertise, resources, or fear of losing competitive advantages. |
| **E** | Difficulty obtaining data from suppliers for unwillingness of sharing | 15% of manufacturers (Tier 2) do not provide data on materials, slowing down processes. |
| **H** | Difficulty obtaining data from suppliers for unwillingness of sharing | Some suppliers resist sharing information, citing industrial secrecy. |
| **A - I** | Issues with Asian suppliers | Chinese production is often less transparent and more difficult to verify. |

*Table 20. Challenges and obstacles faced in sustainability requirements and certifications in contracts*

| Company | Sub-theme | Details |
|---|---|---|
| **C** | Challenges in imposing requirements | Contractualizing sustainability requirements is complex due to the many existing binding contractual aspects. |

| | | |
|---|---|---|
| **E** | Code of conduct | Each company has its own code of conduct developed by its legal team, and as a result, they often do not want to sign those of other companies. |
| **I** | Compliance verification | Requirements still do not include formal escalation measures, which weakens their effectiveness. |
| **H** | Market perception | It is harder to impose sustainability requirements in markets that are not predisposed to them. |
| **A** | Requirements verification | It is still difficult to verify compliance with sustainability requirements because they are relatively new. |
| **E** | Obtaining certifications | In case of material shortages, there is pressure to replenish supplies quickly, but manufacturers often say, "Buy it first, then I will provide the material compliance." At the same time, E cannot purchase components that do not meet compliance requirements. |

### *6.2.3 Green Innovation*

*Table 21. Challenges and obstacles faced in green Innovation*

| Company | Sub-theme | Details |
|---|---|---|
| **A** | Difficulties with alternatives | More sustainable alternatives are often more expensive, increasing product costs and prices for customers. |
| **A** | Difficulties with alternatives | Sometimes, a sustainable alternative does not yet exist, or it creates additional issues. |
| **F - H** | Lack of standardization | The lack of standardization creates uncertainty about the outcomes of sustainability actions, making it difficult to implement new green strategies and technologies. |
| **A** | Technological challenges in design | It is necessary to understand the characteristics of recycled materials to be able to use them, as they have different properties compared to new materials depending on how they were recovered. |
| **C** | Technological challenges in design | The variety and complexity of components create a significant barrier to accurately calculating emissions and implementing a systematic approach to eco-design. |

*Table 22. Challenges and obstacles faced in certifications and Life Cycle Assessment (LCA)*

| Company | Sub-theme | Details |
|---|---|---|
| **C – E - H** | Product complexity | A vast number of components need to be certified. |

*Table 23. Challenges and obstacles faced in client-focused sustainability strategy*

| Company | Sub-theme | Details |
|---|---|---|
| **I** | Difficulty in meeting customer demands | Large clients, such as Silicon Valley companies, often make highly detailed requests perceived as unrealistic. The company works hard to push suppliers to improve but cannot demand results that are not backed by scientifically validated processes. |
| **F - D** | Difficulty meeting customer requests | Each client requires suppliers to complete a specific training or fill out a questionnaire with similar but slightly different questions, which demands significant time and resources. |
| **A** | Lack of standardization | There are not established sustainability benchmarks, as it does for quality and punctuality. This prevents the market from developing recognition mechanisms and contractual requirements for suppliers with lower emissions, which could serve as an incentive for companies to reduce their environmental impact. |
| **D - F** | Power of costumers | Large customers can exert strong pressure to meet sustainability requests. |
| **F** | Power of costumers | The company seeks to follow its own sustainability strategy but must adapt to customer demands. |
| **H** | Low importance of sustainability criteria in the market | In competitive markets price dominates over other factors, limiting the ability to enforce environmental requirements. |
| **A** | Reduced importance of sustainability criteria in the market | Product quality remains the top priority for customers, relegating sustainability to a secondary role. |
| **A** | Reduced importance of sustainability criteria in the market | Not all clients provide financial incentives to support the additional costs of sustainability. |

*Table 24. Challenges and obstacles faced in integration of sustainability into corporate strategy*

| Company | Sub-theme | Details |
|---|---|---|
| **D – E – F** | Limited resources allocated by companies | Lack of resources dedicated to data collection because the value of ESG is not yet fully recognized, as it has not generated significant economic returns. Additionally, the workload is heavy because much of the work is manual. |

## 6.3 Complexity of the supply chain of high-tech products

The high level of complexity within the supply chains of these companies poses a primary challenge. They are sourcing from many suppliers, spanning various tiers and in different regions, making it resource-intensive to conduct comprehensive assessments or gather reliable data. In some cases, simply identifying the correct contact person for data requests can become an obstacle. Also, this is compounded when some suppliers are based in China, regions with less stringent environmental and labor regulations, and companies are less prone to transparency.

Power imbalances further complicate matters: when the company represents only a small fraction of another company's business, the latter can easily ignore the request. Conversely, large clients can place significant pressure on the companies themselves to meet specific sustainability criteria.

In general, companies find that suppliers are reluctant to share data, afraid of losing their competitive advantage and expertise, or are unable to calculate it. Also, when data is available, it may be incomplete or lower quality, limiting the use it can provide. These dynamics make it difficult for companies to gain full visibility over their supply chains and to ensure compliance with sustainability standards.

## 6.4 The standardization challenge

The main issue emerging from the interviews is the general lack of standardization in sustainability metrics and practices. In fact, they lament differences in units of measurement, data-collection processes and methods, and certification requirements. This applies in many situations. For example, when companies receive sustainability data from their actual or prospect suppliers, they must manually reconcile it to be able to compare their performances. This process is both time-consuming and prone to errors and impedes the capacity of the companies to perform a correct assessment of their products and of comparing producers.

There is also a lack of standardization in the certification and questions posed by customers and perspective ones; they request information, but each questionnaire differs slightly, forcing companies to respond individually.

Also, without a clear benchmark or universally recognized framework for environmental metrics, many firms struggle also in comparing their performance with the one of competitors, making it difficult to reward genuine improvements or transparently penalize underperformance. A general standard, instead, would create a strong incentive for sustainability. Without clear standards and rules, it is easier for companies to hide bad sustainability behaviour, or look better than they actually

are. In conclusion, the interviews clearly highlight the need for greater standardization in sustainability practices. The absence of shared metrics and procedures not only creates inefficiencies but also opens the door to ambiguity and, in some cases, greenwashing.

## 6.5 Data quality issues

Data quality remains a core issue for many companies attempting to integrate sustainability into their operations. In several cases, the problem originates from the absence of robust information systems. Without advanced tools, companies are often forced to rely on manually collected data, static spreadsheets, or estimates.

Transparency is another critical factor. Many suppliers, especially in highly competitive or low-margin sectors, are hesitant to share detailed environmental or social data. This reluctance may stem from fears of exposing weaknesses, lack of internal expertise, or the absence of clear contractual obligations. As a result, the data that companies do receive is often self-reported, lacking independent verification, and varies significantly in format and completeness.

Geographical factors further exacerbate the issue. Suppliers located in regions with less stringent environmental regulation, such as the Asian countries where the companies in analysis declare to source, often lack the tools or regulatory incentives to collect high-quality ESG data. Others struggled simply to identify the right point of contact within a supplier's organization.

This issue is relevant and should be prioritized, because without reliable data, sustainability strategies risk remaining superficial and disconnected from actual performance.

## 6.6 The lack of efficient digital tools

Another significant barrier highlighted across several interviews is the limited availability of adequate digital tools to support sustainability efforts. Many companies still rely on fragmented systems, manual spreadsheets, or generic procurement platforms that were not designed with ESG data in mind, like procurement ones. These tools often lack the specific functionalities, which are increasingly necessary to monitor and report on sustainability performance in a reliable way: data analysis tools, integrations with sustainability resources, dashboards to compare suppliers, for example. In this way, data collection becomes time-consuming and error-prone. Companies struggle to track information consistently, cannot identify trends, verify improvements, or respond promptly

to requests from clients or auditors. In some cases, sustainability assessments are carried out only once per year, or manually on a small sample of suppliers.

The lack of digital maturity also affects credibility. Without robust systems, it becomes harder to justify claims, ensure traceability, or meet growing demands for transparency from clients and regulators. To move forward, companies will need to invest in good Green Information Systems: this transition will require resources, but it is essential for embedding sustainability into day-to-day operations, rather than treating it as a separate reporting task.

# 7. Implementation and maturity of sustainability strategies

## 7.1 How do the companies address the sustainability challenge?

In this section, the actions undertaken by companies and the difficulties they face is detailed as it emerges from the interviews and integrated with the responses provided in the questionnaires.

### *7.1.1 Company A*

For company A, sustainability is seen as an added value rather than a driving element of its strategy. In ESG actions, it tends to have a reactive approach and encounters various difficulties in carrying them out and complying with regulations, for which it complains about a lack of attention from legislators: *"When we write regulations or set targets, we must also take into account what the alternatives are, how much they cost, and who pays for them."* This theme was repeated several times in the interview, with green innovation and client-focused sustainability approach being the most treated in the interview.

As a demonstration of its reactive approach, it conducts LCA assessments only when requested by the client. Even in eco-design, A claims to consider almost all aspects of sustainability in its design process, but only when required by the market. In fact, this design method is carried out solely at the request of customers, through products referred to as "project trade," which are developed as: *"On a commission basis, we define the solutions regarding an object with a lower environmental impact."* Due to the characteristics of the products, it launches on the market, the company struggles to integrate recycled materials, as they do not guarantee the preservation of required properties. Furthermore, it believes that there are currently no suitable sustainable alternatives for the components it needs and complains that the existing ones are either more expensive or could cause other types of damage.

On the other hand, regarding the reduction of resource and energy consumption during production, the company makes numerous efforts to improve. However, these investments seem to be more focused on cost optimization rather than a structural commitment to sustainability, also because clients do not provide clear economic incentives for environmental improvements.

Company A has a global supply chain and declares that it struggles to involve suppliers in ESG practices and to obtain data. This is likely since its suppliers are predominantly located in China, and geographical distance, as well as a lack of transparency, could be one of the causes of these

difficulties. It finds particular challenges in obtaining data from smaller manufacturers, who do not have suitable tools to measure sustainability data: *"The smaller and more niche the company is, the more difficult it naturally becomes. When we source something from an artisan, understanding how much $CO_2$ they emit is more difficult."*

The company requires certifications but has not yet implemented an auditing system to verify compliance, relying for now solely on the documentation provided. Therefore, another limitation to improving corporate sustainability is the lack of structured verifications on the environmental compliance of suppliers: *"It is still difficult to verify compliance with the requirements because they are new. In A, this is managed by the quality department."*

Regarding the information system for managing sustainability-related data, the internal system is described as highly developed, designed to track production information and share it within the company, while the system for communication with suppliers is considered moderately ready. This theme was not treated in the interview, so we do not know the details of their information systems. Additionally, the company states that clients do not prioritize sustainability aspects as much as product quality. However, they frequently make sustainability-related requests, which A attempts to address. Sometimes, meeting these requests results in higher costs, which the company tends to pass on to the client whenever possible.

### *7.1.2 Company C*

Company C believes that adapting to sustainability principles can provide interesting competitive advantages to outperform the competition, as its main competitor is a leader in sustainability. For this reason, it is committed to quickly adapting to market and, above all, customer demands, and, whenever possible, seeks to anticipate them in order to remain competitive.

It considers LCA certification very important and has currently conducted LCA on half of its product catalogue. They perform two types, one for EPD certifications to be appealing in the market and one with primary data for eco-design. To make the process even more effective, the company would need a greater amount of primary data. As they state: "*For eco-design, obviously, we need primary data because how can I say this option is better than another if I am using an average?*" However, they are currently struggling to obtain them. Eco-design is still under study: they are conducting pilot studies to collect primary data and use it for comparative analyses on materials and products. Nonetheless, they state that all sustainability aspects are considered in the design process.

Supply chain management was the theme treated more in depth in the interview. In general, their strategy is fairly structured, with direct involvement of all Tier 1 suppliers and periodic audits through EcoVadis. At present, they can obtain data with detailed information on $CO_2$ emissions from Tier 1 suppliers and occasionally from Tier 2. Although they claim to easily obtain information from suppliers, they acknowledge shortcomings in their information systems for supply chain management and primary data collection. As they explain: "*We are starting to work on understanding how to develop an information system to obtain sustainability data because, at the moment, EcoVadis operates at a different level of detail than what we require from suppliers—it does not go into such depth on processes.*" On the other hand, internally, they claim to have an excellent level of information sharing and a well-structured database to support it.

They are unable to include contractual clauses on sustainability aspects due to the high number of existing clauses and, above all, the difficulty of verifying them. Moreover, significant resources must be invested to support Tier 1 suppliers to ensure this works, also because many of them are small and lack the necessary capabilities. They do not intend to engage with Tier 2 suppliers because these are very large multinational corporations that are difficult to influence. However, they seek to influence them indirectly, "*by pushing our Tier 1 suppliers to request more sustainable materials from them.*"

### *7.1.3 Company D*

For Company D, sustainability is a central element of its strategy, although its approach is still evolving. The company has established an ESG committee to assess risks and guide corrective actions throughout the supply chain. About it, they say: "*We decided to set up a supplier ESG due diligence committee and it's made up of different functions that are closely involved in identifying and assessing ESG risks with our suppliers*." However, sufficient resources have not yet been allocated to this initiative.

In terms of eco-design, D claims to take various sustainability aspects into account when designing its products. Furthermore, they state that the initiative to implement eco-design originates from the company itself. However, LCA is primarily conducted in response to customer requests rather than as a proactive tool for innovation, probably because there is currently no adequate information system to support green innovation, and at this stage, it is mainly used for disclosure.

The company's supply chain is a critical point for implementing its sustainability strategy. “D” focuses primarily on Tier 1 suppliers, using tools like Integrity Next to monitor environmental

compliance and conduct ESG audits. However, the lack of standardization in sustainability data and cultural challenges with suppliers, especially in Asia, make it difficult to obtain reliable and comparable information. "*We have a global supply chain made up of several tiers of suppliers and the data quality is an issue, sometimes we don't even have the right contact details of who in the organization of the supplier to approach in order to get environmental information.*" The company has a scorecard system to monitor supplier sustainability and initiate corrective actions, but the actual level of supplier engagement depends on their size and strategic importance.

On the customer side, D recognizes that the demand for sustainability is increasing, but ESG criteria often do not carry significant weight in purchasing decisions. However, the company has observed growing interest from customers and investors in sustainability, which could push it to strengthen its commitment in the future, especially given the company's strong focus on meeting customer demands.

Regarding Green Information Systems, the company states that it has a developed information system to track and monitor internal environmental performance, with a good level of information sharing within the organization. However, the situation is very different within the supply chain: the sharing of environmental data with suppliers and customers is still limited, and the flow of information between supply chain actors is poorly integrated, with data not being available in real time. This is due to the lack of advanced information systems among suppliers, which hinders improvements in environmental performance across the entire value chain.

### *7.1.4 Company E*

Company E is approaching sustainability considerations to meet customer demands and environmental regulations and has various plans and projects that are still in an early stage of implementation. Speaking about its strategy, it states: "*In the end, we adapt to what customers and regulations require. We do not go beyond what is necessary."*

They have an information system for eco-design that allows them to calculate the product's carbon footprint in real-time and to prioritize suppliers with a lower environmental impact. However, this is not applied to all products but only to those where the lower environmental impact translates into a recognized economic added value. They believe that "*If the lower environmental impact is not an economically recognized added value, it does not make sense to develop it*." Additionally, in their eco-design approach, they declare that they primarily focus on reducing the impact of

transportation and secondarily on reducing energy consumption in production, contrary to what might be expected, and no consideration is given to circular economy principles.

To monitor the supply chain, in their case, Tier-1 suppliers are distributors, so the first truly relevant tier is Tier-2. To do this, they currently do not have an information system in place; Tier-1 suppliers are assessed qualitatively, while information from Tier-2 suppliers is collected through questionnaires administered via Achilles or Eco Vadis, which are then analysed manually, overloading their ESG department. Suppliers are not very collaborative in providing data and certifications, both Tier-1 and Tier-2, with only 15% of Tier-2 suppliers responding. To find the necessary data, they often rely on sustainability reports, from which they manually extract useful information, even though the process is time-consuming and inefficient. The company states that "*Even for legally mandatory aspects, such as material compliance, we struggle to get responses*." However, when mandatory regulations are in place, obtaining certifications from clients is easier. In general, their suppliers are larger companies and therefore have little interest in responding to their ESG requests.

Certifications are carried out carefully and very quickly, managing to complete an LCA in just two weeks, but this is done only at the request of a customer or prospective clients.

In contracts with their suppliers, they include the General Purchasing Conditions, which require signing the code of conduct and compliance with mandatory regulations, such as REACH and RoHS. More advanced certifications, such as full materiality and ISO 14001, are preferred but not essential.

### *7.1.5 Company F*

The integration of sustainability aspects into F's strategy is still at an early stage, despite its recognized importance. As evidence of this, they have established an internal ESG committee, which, however, consists of only one person.

Regarding the supply chain, the company struggles to obtain information from suppliers. This is partly due to their limited data sharing but also to the lack of a fully integrated information system, which reduces the efficiency of ESG data exchange. In fact, they are developing a system for collecting supplier data, but it is still in the testing phase, so information management remains largely manual. Internal information management within the company is also not well integrated.

New suppliers are required to complete ESG questionnaires through Eco Vadis, obtaining a score that determines their eligibility. If the score is too low or serious violations are identified, the supplier is excluded. However, it is unclear whether this evaluation is updated over time or if it also

applies to existing suppliers in the supply chain, as the interview only mentions new suppliers. Moreover, it is not clear whether this process is conducted for all suppliers or just for a selection. In general, this process is long and costly, also due to the lack of metric standardization. Sustainability requirements in contracts were not mentioned in the interview, so we do not know if the company enforces its request through this tool.

Also the realization LCA was not discussed; it seems that although the company recognizes the great value of LCAs, it appears that they are still not systematically conducted. This is because there is no adequate information system to support them.

Eco-design is driven by customer requests and economic and legislative considerations rather than by internal initiative. However, in new products, attention is given to reducing resource consumption, improving recyclability, and minimizing waste and hazardous substances.

The company's response to sustainability requests from customers varies depending on their strategic importance. If a customer is large or relevant, the company seeks to respond quickly to ESG requests; otherwise, the action is postponed or excluded. However, the company follows its own ESG strategy and does not adapt to all customer requests. Although the company provides ESG data to customers, data sharing is not reciprocal: "*Our customers don't share environmental information with us*." This lack of sharing limits the ability to compare and improve based on industry benchmarks. This theme was treated in detail in the interview, highlighting its importance for the company.

The company complains about the lack of standardization in ESG reporting. The sustainability officer must dedicate a large portion of their time to translating reports into the metrics required by different clients in various countries, reducing the ability to focus on more meaningful activities. ("*50% of your time you are reporting, to different regulations, so different things according to the specific regulations. It's crazy*.") Additionally, internal reporting is not yet automated.

### *7.1.6 Company H*

The company "H" fully integrates sustainability into its strategy, as demonstrated by its SBTi-certified sustainability roadmap. However, it faces challenges in ensuring data transparency and engaging the entire supply chain.

Being a commercial company, it does not produce internally, develop certifications, or conduct LCAs, but it has contributed to a certification for tracking recycled materials. Nevertheless, it requires EPDs from its suppliers, although they are difficult to compare: *"EPDs are our vademecum,*

*but comparing two different EPDs, over time, I have realized, is very complicated. […] There is no single standard that allows for a true comparison."* In fact, suppliers use different metrics, making the evaluation even more complex: *"Now, some suppliers upload the EPD Italy, for example, for photovoltaics with a measurement unit of kilograms of $CO_2$ per kilowatt-hour, while others upload the Norwegian EPD, which instead uses kilograms of $CO_2$ per square meter of panel, making it difficult to compare the data. Or they use the International EPD per unit, meaning kilograms of $CO_2$ equivalent per single panel."*

Since it does not develop products directly, eco-design is not an active part of H's business model. However, thanks to its influence, it manages to encourage suppliers to develop more sustainable solutions, especially in markets where it has greater power.

In "H"'s supply chain, information sharing is limited, both in terms of receiving information from customers and suppliers and in terms of sharing information by H itself. The company does not actively share environmental information with customers and suppliers, nor does it receive structured data from supply chain partners, which limits overall transparency. The company also states that it has a limited information system for managing data, both internally and from suppliers. Currently, it uses We Buy, which is not optimized for sustainability management, and is developing a new system to improve data collection. However, data quality remains a critical issue, as it is primarily based on self-declarations without advanced verification tools. This is a critical point for company strategy, and it was discussed in detail in the interview.

Within its supply chain, "H" adopts a system of sustainability incentives, offering advantages in tenders to suppliers that adopt environmental certifications or sustainability policies. Some requirements also extend to Tier 2+, especially in the supply chains of critical raw materials such as lithium, aluminium, and copper, where greater traceability is required to comply with regulations. For certain products, the company collects details on the origin of materials through *"material passports"*, documents that detail raw materials and product components. However, supplier sustainability verification is based on self-declarations and documents uploaded to the procurement portal, without direct verification or third-party audits. Contracts include binding sustainability clauses, but the company does not yet have an effective control strategy to ensure compliance.

"H" also seeks compromise with suppliers, stating: *"When a supplier commits to obtaining a specific certification within a certain number of months after signing the contract and fails to do so, we try to understand the reason. […] We also have penalties, but we often find a compromise."* Furthermore, it faces difficulties in imposing ESG requirements in more competitive markets, where

price is the dominant factor, or in those less culturally inclined toward sustainability. However, it has observed a shift in the market: *“In five years, I have seen a change: from an outright no to product certifications to a greater openness. […] Step by step, the market itself will realize that certain aspects of sustainability are in the interest of companies.”*

### *7.1.7 Company I*

The company "I" integrates sustainability into its corporate strategy by utilizing innovative and highly advanced technologies, although some systems are still under development.

Currently, the company has a well-developed database to monitor the environmental performance of its products and internal operations. However, this system does not extend to the supply chain, where information sharing with suppliers and customers is limited.

To improve transparency, they are working on a system that enables real-time information sharing. They possess a large amount of data, but as they state, *"We have a lot of information, but most information is, let’s say, based on statistics, based on self-declarations, based on audits, but it’s not real-time from the source information."* Therefore, these data cannot be used as effectively as desired for eco-design and are not easily utilized for decision-making.

To compensate for missing information, they are experimenting with Green Digital Twins, which simulate the effects of various design and sourcing decisions. However, this system is still not very accurate, as it relies on statistical data instead of real-time information. Additionally, they use blockchain technology (Aussie Green Program) to aggregate and certify the Product Carbon Footprint (PCF) throughout the supply chain. Nevertheless, this technology is currently limited to tracking PCF only.

It is not clear if they perform LCA or other certifications, since this was not mentioned in the interview.

Suppliers tend to be reluctant to share data, particularly in China, where transparency has historically been low, although some recent improvements have been observed. Tier 1 suppliers are directly engaged and supported through financial and non-financial incentives to improve their sustainability performance. The company initially engages them using a "*soft power*" approach, followed by well-defined contractual clauses, which also include non-negotiable sustainability requirements. However, there are no formal escalation mechanisms in place, limiting the enforcement of these requirements.

They are also launching a pilot study to improve transparency and calculate emissions. Tier 2 suppliers are contacted only in high-risk cases, and there is no intention to expand this monitoring, as it is deemed unnecessary: *"There is certainly less need to qualify or to audit from a process point of view beyond Tier 1, because we see that our Tier 1 has their suppliers well controlled, and they control their suppliers as well."*

In business operations, the company primarily aims to meet customer sustainability requirements, rejecting only those they perceive as unrealistic, which sometimes come from large corporate clients with very high standards. They optimize their responses to customers with standardized answers, integrating additional information where needed to fill any gaps.

## 7.2 Perception and practice in Green Information Systems adoption

*Table 25. Green Information Systems implementation across companies: self-reported scores vs strategy description from the inteview*

| Company | Questionnaire | | Interview | |
|---|---|---|---|---|
| | Internal Database* | Supply Chain IS** | Strategy Summary | Maturity Level |
| A | 3 | 3 | (not mentioned) | / |
| C | 5 | 2 | Uses EcoVadis for secondary data to create EPDs. Monitors $CO_2$, energy, waste, water for Tier 1 suppliers | 4 |
| D | 5 | 1 | Collects sustainability data on “WeBuy”, which is the procurement portal, so it is not fully optimized. Developing a new system to improve supply-chain data management | 3 |
| E | 4 | 1 | Plans to implement a service like EcoVadis for suppliers | 2 |
| F | 1 | 2 | Lacks digital tools to track supplier sustainability performance. They are developing a tool to track suppliers, but it is still in the testing stage | 2 |
| H | 2 | 2 | Collects sustainability data on the procurement portal, not fully optimized. Developing a new system to improve supply-chain data management | 3 |
| I | 5 | 1 | Developing an advanced IS to improve real-time supply chain visibility with AI and machine learning. Testing blockchain-based solutions to certify Product Carbon Footprint data | 5 |

When comparing the results from the questionnaires and the interviews, some misalignments emerge between companies' self-assessment declared in the questionnaires and the actual implementation of Green Information Systems as found in the interviews.

Across the sample, we note a general trend: companies that rely on external platforms like EcoVadis or IntegrityNext tend to give themselves lower scores in the questionnaire, likely reflecting an awareness that these tools are not yet fully integrated into their internal systems. On the other hand, companies relying on internal or in-house tools sometimes report higher scores, especially about the database, even if they are not always fully supported by the level of detail or performance described in the interviews.

## 7.3 Level of maturity in the implementation of the sustainability strategy

The companies are evaluated according to the scoring system shown in Table 25, which assigns maturity levels from 1 (No recognized presence of the strategy) to 5 (Advanced and fully integrated strategy). For each strategy, the maturity levels are linked to specific criteria. To make the assessment, maturity scales have been defined, describing the typical actions or outcomes that characterize each stage: from absent to basic, evolving, advanced, and fully integrated. These benchmarks help interpret where each company stands in practice. After this, a series of tables presents the scores assigned to each company based on how their actual practices align with the criteria. Finally, a final summary table brings all the results together, offering a clear overview of how the different strategies are being implemented across the sample.

*Table 26. Scoring legend*

| Score | Description |
|---|---|
| 1 | No recognized presence of the strategy |
| 2 | Reactive and unstructured approach |
| 3 | Evolving approach, with good initiatives but not yet fully consolidated |
| 4 | Advanced strategy with clear tools and objectives |
| 5 | Advanced and fully integrated strategy |

### *7.3.1. Green information systems*

*Table 27. Scoring legenda - Green information systems*

| Maturity level | Criterias |
|---|---|
| 1 | • No digital systems dedicated to collecting sustainability data from suppliers |
| 2 | • Data may be gathered manually or via simple questionnaires/spreadsheets<br>• Limited or no integration with other business processes |
| 3 | • A structured platform or portal is in place, covering at least Tier 1 suppliers<br>• Some automated functions, but the system is not fully integrated |
| 4 | • Specialized tools (e.g., EcoVadis, IntegrityNext) or customized solutions systematically gather, consolidate, and analyze supplier sustainability data, potentially including Tier 2 |
| 5 | • End-to-end digital integration using advanced technologies for real-time data collection and validation<br>• The organization regularly uses collected data to inform decisions, audits or sample checks verify accuracy |

*Table 28. Suppliers' maturity levels - Green information systems*

| Company | Score | Strategy |
|---|---|---|
| A | / | (not mentioned) |
| C | 4 | Uses EcoVadis for secondary data to create EPDs. Monitors $CO_2$, energy, waste, water for Tier 1 suppliers. |
| D | 3 | Collects sustainability data on "WeBuy", which is the procurement portal, so it is not fully optimized. They are developing a new system to improve supply-chain data management. |
| E | 2 | Plans to implement a service like EcoVadis for suppliers (many suppliers are already on the platform). |
| F | 2 | Lacks digital tools to track supplier sustainability performance. They are developing a tool to track suppliers, but it is still in the testing stage. |
| H | 3 | Collects sustainability data on "WeBuy", which is the procurement portal, so it is not fully optimized. They are developing a new system to improve supply-chain data management. |
| I | 5 | Developing an advanced data system to improve real-time supply chain visibility, leveraging AI and machine learning. Testing blockchain-based solutions through the Aussie Green program to aggregate and certify Product Carbon Footprint (PCF) data. |

### *7.3.2. Sustainable supply chain management*

#### 7.3.2.1 Supplier engagement in ESG practices

*Table 29. Scoring legenda - Supplier engagement in ESG practices*

| Maturity level | Criterias |
|---|---|
| 1 | • No monitoring of suppliers' ESG performance |
| 2 | • Suppliers are engaged only in response to issues or external pressure: clients, market, authorities<br>• No standardized procedures, sporadic initiatives |
| 3 | • Clear methods and objectives to monitor and improve suppliers' ESG performance (audits, KPIs, improvement plans)<br>• Basic policies (e.g., codes of conduct) to engage suppliers on ESG aspects, but not yet systematic<br>• Initial evaluations (e.g. simple questionnaires) requiring minimal compliance, without a continuous improvement process |
| 4 | • Incentives are given to suppliers to foster ESG actions<br>• Collaboration with suppliers is formalized in contracts and agreements on sustainability<br>• Lower tier suppliers are influenced |
| 5 | • ESG management of suppliers is integrated in the relationship with the supplier: selection, evaluation, support, training<br>• Long-term partnerships with suppliers<br>• Lower tier suppliers' engagement |

*Table 30. Suppliers' maturity levels - Supplier engagement in ESG practices*

| Company | Score | Strategy |
|---|---|---|
| A | 2 | It recently started involving tier 1 suppliers, upon client request. The supply chain is mostly based in China, making it difficult to follow ESG actions. |
| C | 4 | It influences tier 1 suppliers to purchase more sustainable materials, affecting also tier 2. It provides support for emission calculations and bettering internal processes. |
| D | 4 | Not only it evaluates the suppliers, but it is also able to guide them towards step-by-step improvements. It requires new and existing suppliers to respect many conditions, like signing the Code of Conduct and fill a scorecard and take corrective actions when needed. |
| E | 3 | It evaluates suppliers and plans to do it with EcoVadis. In case of low scores, suppliers are engaged for improvements rather than excluded. It engages with Chinese suppliers to encourage them to improve, even with small actions. |
| F | 3 | It evaluates suppliers' ESG actions with the EcoVadis questionnaire, giving them a score and identifying risks. Low scores and critical failures cause an exclusion. |

| | | |
|---|---|---|
| H | 4 | It engages with tier 1 suppliers and encourage them to pass the requirements also to lower tiers. They are given help, incentives and guidance. |
| I | 5 | It involves only tier 1 suppliers, but they must pass the requirements to lower tiers. All must sign the Code of Conduct. However, formal audits mainly target tier 1. Tier 1 is also given financial and non-financial incentives to improve sustainability, starting with a "soft power" and partnership approach but planning future mandatory requirements, with penalties for non-compliance. It recently launched a pilot study to collect emission data, focusing on Tier 1 and some Tier 2 "hotspots." |

#### 7.3.2.2 Transparency and data sharing

*Table 31. Scoring legenda - Transparency and data sharing*

| Maturity level | Criterias |
|---|---|
| 1 | • No systematic collection of supplier data on sustainability<br>• No policies or processes in place to request or verify supplier information |
| 2 | • Data is collected only when required by customers or regulation, often through basic questionnaires<br>• Data gathering methods have significant gaps<br>• Little or no verification of the data provided |
| 3 | • Organized approach for data collection is in place<br>• Data collection may extend beyond Tier 1 suppliers in higher-risk areas or on a pilot basis<br>• Audits/validations are limited, but efforts are underway to improve consistency |
| 4 | • Well-defined processes and technologies (e.g., EcoVadis, IntegrityNext, etc.) used across a broad supplier base, including some Tier 2 engagement<br>• Regular audits or sample checks to verify accuracy |
| 5 | • Multi-tier data collection<br>• Strong verification processes<br>• Data-sharing is embedded in contracts |

*Table 32. Suppliers' maturity levels - Transparency and data sharing*

| Company | Score | Strategy |
|---|---|---|
| A | 2 | It collects data from suppliers to satisfy costumers' request. Faces difficulties in doing so, especially from small suppliers lacking measurement tools. |
| C | 4 | It collects data, such as carbon emissions via EcoVadis for ~150–200 Tier 1 suppliers, and occasionally involves Tier 2. Plans sample audits to verify environmental data. |

| | | |
|---|---|---|
| D | 3 | Conducts supplier due diligence only on Tier 1 for resource constraints. Uses IntegrityNext for audits. |
| E | 3 | It uses EcoVadis/Achilles to assess T2, while T1 is assessed more qualitatively. T3 is generally excluded unless conflict-mineral regulations apply. Uses suppliers' sustainability reports for finding data. It does not carry direct audits |
| F | 2 | Data from suppliers is collected through questionnaires; there are no mentions of any structured approach or data updates. |
| H | 3 | They perform the mapping of Tier 1, and Tier 2 if risk is high. It collects sustainability data from suppliers primarily through procurement systems: these are not designed specifically for sustainability reporting, and data handling results complex and as it is manually performed. No structured third-party audit system, some verifications are done manually. Material composition details are requested to track the use of recycled and raw materials, through "material passports" (self-reported). |
| I | 4 | It collects data directly from Tier 1 suppliers and invites them to do the same. It is developing AI/Machine Learning techniques to improve transparency. Uses third-party audits in higher-risk sectors for Tier 2. |

#### 7.3.2.3 Sustainability requirements and certifications in contracts

*Table 33. Scoring legenda - Sustainability requirements and certifications in contracts*

| Maturity level | Criterias |
|---|---|
| 1 | • The company do not require certifications or other sustainability requirements |
| 2 | • Sustainability clauses appear only in response to external pressures (customer demands or legal requirements) |
| 3 | • Contracts include sustainability requirements and some recognized certifications<br>• No standardized approach to requesting certifications |
| 4 | • Contracts incorporate some sustainability requirements and certification requirements<br>• Compliance checks (audits or reviews) happen occasionally or for select suppliers |
| 5 | • Contracts incorporate many sustainability requirements and certification requirements<br>• Well-structured verification processes (regular audits, performance reviews), with penalties or incentives based on results |

*Table 34. Suppliers' maturity levels - Sustainability requirements and certifications in contracts*

| Company | Score | Strategy |
|---|---|---|
| A | / | (not mentioned) |
| C | 1 | It still has not contractualized sustainability requests for suppliers, in addition to current regulatory requirements, for regulatory complexity. |

| | | |
|---|---|---|
| D | 3 | Suppliers they work with must confirm adherence to the Supplier Code of Conduct, which includes "Green Procurement Requirements". This specifies the required environmental expectations, such as compliance with regulations like RoHS and REACH and the provision of environmental data, including GHG emissions. |
| E | 3 | It uses General Purchase Conditions as sustainability requirements (code of conduct, mandatory legal norms, optional ISO 14001, etc.). |
| F | 1 | While suppliers must meet some requirements initially, there is no mention of enforcement through contracts. |
| H | 5 | The company integrates binding sustainability clauses into contracts, imposing environmental certification requirements and incentive criteria (sustainability K) to encourage suppliers to adopt more sustainable practices. T1 must sign the Code of Conduct, T2 must ensure compatibility with it. There are penalties for not compliance. |
| I | 4 | “Ready for Business Requirements” (mandatory conditions to initiate business relationships with the company) include sustainability aspects and are non-negotiable. Currently, sustainability requirements imposed on suppliers do not include formal escalation measures, but they are expected to become binding in the future. |

### *7.3.3 Green Innovation*

*Table 35. Scoring legenda - Green Innovation*

| Maturity level | Criterias |
|---|---|
| 1 | • No eco-design or consideration of recycled and low-impact methods |
| 2 | • Sustainable features are added only when a customer or regulation demands it |
| 3 | • Some pilot projects and small eco-design efforts are underway (e.g., comparative material analyses) |
| 4 | • Systematic integration of eco-design in product development, supported by data-driven tools (e.g., real-time carbon footprint calculations)<br>• Push suppliers for more sustainable products<br>• Sustainability criteria guide significant design decisions, though not all products may be covered or fully optimized |
| 5 | • Eco-design principles and sustainable materials are the default in new product development, using advanced technology in support of it<br>• Green innovation is a strategic priority, engaging multiple tiers of the supply chain and continuously improving on ESG aspects |

*Table 36. Suppliers' maturity levels - Green Innovation*

| Company | Score | Strategy |
|---|---|---|
| A | 2 | Only develops more sustainable products upon specific client requests ("project trade"). Not ready to adopt recycled materials as a standard |
| C | 3 | In a transition phase towards the implementation of eco-design, it does pilots project to collect primary data and conduct comparative analyses on materials and product solutions |
| D | 1 | Data systems aren't yet advanced enough to support green innovation, currently used more for disclosure |
| E | 4 | It uses a real-time carbon-footprint system for mechanical and electronic components during product development, helping to prioritize lower-impact suppliers/materials. Eco-design is not done for every product, but applied only where it adds a value that is recognized in the market |
| F | 2 | It does not automatically adopt sustainable materials unless customers or policies require it |
| H | 4 | Being a commercial firm, they do not design the products they commercialize. However, they push suppliers to create more sustainable products. |
| I | 3 | They recognize the importance of eco-design for decarbonization but face challenges due to the lack of primary data from Tier 3–4 suppliers. They aim to develop a system for real-time eco-design and are working on bridging data gaps through a "Green Digital Twin" |

### *7.3.4 Other sustainability strategies*

#### 7.3.4.1 Certifications and Life Cycle Assessment (LCA)

*Table 37. Scoring legenda - Certifications and Life Cycle Assessment (LCA)*

| Maturity level | Criterias |
|---|---|
| 1 | • No environmental or social certifications<br>• No Life Cycle Assessment (LCA) conducted on products/services |
| 2 | • Basic certifications (ISO 9001, ISO 14001) only pursued to meet market or legal requirements<br>• LCA considered only sporadically |
| 3 | • The company obtains more advanced certifications (ISO 45001, ISO 50001)<br>• LCA analyses are partial and not extended across the full product portfolio |
| 4 | • Multiple certification schemes (environmental, social) regularly adopted<br>• LCA conducted on key products/processes, with findings integrated into product and process design |

| | |
|---|---|
| 5 | • Certifications and LCA are fully integrated into the company's strategy<br>• All major products have an LCA |

*Table 38. Suppliers' maturity levels - Certifications and Life Cycle Assessment (LCA)*

| Company | Score | Strategy |
|---|---|---|
| A | 2 | Performs EPD certifications only upon client request |
| C | 3 | They carry out two types of LCA: one for EPD (using secondary data, which is preferred by certification bodies) and one for eco-design (using primary data). Nearly half of the product portfolio is covered by EPD |
| D | 2 | Carries out LCA upon customer request rather than as a standard practice |
| E | 5 | They calculate product carbon footprints in real time as the product is developed. LCAs are performed quickly upon customer request. Many supplier data are gathered from sustainability reports |
| F | 1 | LCA is not yet systematically conducted LCA for all products, even though they see its potential value |
| H | / | (not mentioned) |
| I | / | (not mentioned) |

### 7.3.4.2 Client-focused sustainability strategy

*Table 39. Scoring legenda - Client-focused sustainability strategy*

| Maturity level | Criterias |
|---|---|
| 1 | • The company does not address or acknowledge client requests regarding ESG |
| 2 | • Company responds to sustainability demands only if prompted by customers<br>• Prioritization of other factors over sustainability; might occasionally refuse or delay fulfilling requests perceived as less impactful or beneficial |
| 3 | • Increasing willingness to meet client sustainability needs, often adapting offerings if the request aligns with company strategy or if the client is important<br>• Recognizes the competitive advantage of addressing sustainability |
| 4 | • Systematically addresses client requests for sustainability data in a timely manner<br>• Sees value in going beyond minimal compliance to build client loyalty and demonstrate meticulous processes when needed |
| 5 | • Sustainability is integral to client relationships: the company co-creates solutions with clients, proactively offers sustainable options, and adjusts to varied or complex requests<br>• The client's sustainability goals and expectations are embedded in product design, pricing, and lifecycle management |

*Table 40. Suppliers' maturity levels - Client-focused sustainability strategy*

| Company | Score | Strategy |
|---|---|---|
| A | 2 | It commits to meeting the sustainability requirements, with verifications carried out by the quality department. If the client requests it, the company must provide a more sustainable product, but product quality remains the top priority over decarbonization. Sometimes, it requests a higher price for a sustainable alternative, and other times it does not accept it. |
| C | 4 | Responsiveness to client sustainability requests, with strategies evolving based on their needs. Anticipating market sustainability demands to remain competitive compared to competitors. |
| D | 3 | They consider it essential to meet client requests. |
| E | 4 | If a client requests the carbon footprint, it is quickly calculated (within two weeks) to build client loyalty, making the process valuable for them. When an LCA is requested, they are ready to carry it out in a thorough and meticulous manner. |
| F | 3 | The company's responses to clients vary depending on the client's size and impact on the company. If the client is large, they try to act immediately. If the client is small, the request may be postponed to the following year or not fulfilled if it is not considered impactful or useful to the company. In general, they aim to respond to client requests based on how they align with the company's ESG strategy. |
| H | \ | (not mentioned) |
| I | 4 | They strive to satisfy the client. The only requests that are not met are the ones perceived as unrealistic. Client questionnaires: it tries to standardize and provide generic responses to client survey requests due to their complexity, as they receive many from different countries. In some cases, clients are not satisfied with standard responses and make specific requests, which are often difficult to understand or fulfil. |

## 7.4 Summary of sustainability strategy maturity levels

*Table 41. Comparison of maturity levels by company and sustainability strategy, with average scores per strategy and per company*

| Sustainability strategy | A | C | D | E | F | H | I | **AVG** |
|---|---|---|---|---|---|---|---|---|
| Green information systems | / | 4 | 3 | 2 | 2 | 3 | 5 | *3,2* |
| Supplier engagement in ESG practices | 2 | 4 | 4 | 3 | 3 | 4 | 5 | *3,6* |
| Transparency and data sharing | 2 | 4 | 3 | 3 | 2 | 3 | 4 | *3,0* |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Sustainability requirements certifications in contracts | / | 1 | 3 | 3 | 1 | 5 | 4 | *2,8* |
| Green Innovation | 2 | 3 | 1 | 4 | 2 | 4 | 3 | *2,7* |
| Certifications and Life Cycle Assessment (LCA) | 2 | 3 | 2 | 5 | 1 | / | / | *2,6* |
| Client-focused sustainability strategy | 2 | 4 | 3 | 4 | 3 | / | 4 | *3,3* |
| **AVERAGE** | *2,0* | *3,3* | *2,7* | *3,4* | *2,0* | *3,8* | *4,2* | |

Among the strategies, supplier engagement in ESG practices, client-focused sustainability strategy, and Green Information Systems show the highest average scores, indicating they are more widely adopted across the sample. In contrast, Certifications and LCA and Green Innovation have the lowest averages, suggesting they are less developed. They might be less prioritized or more challenging to implement. Looking at the companies, Company I stands out with the highest overall average (4.2), followed by Company H (3.8). On the other end, Companies A and F score lowest (2.0), indicating more limited adoption of the strategies considered.

# 8. Conclusions

This thesis explored the sustainability strategies of high-tech companies in Italy, with a specific focus on their implementation of Green Information Systems (GIS), sustainable supply chain management, and green innovation. Through qualitative analysis of interviews, enriched with quantitative data from questionnaires, the research aims to understand how these companies address their environmental, social, and governance (ESG) responsibilities, to identify the key challenges they encounter, and to assess the maturity of their strategies.

Talking about green innovation, it is important to consider that when finding and adopting technological solutions for environmental challenges, it is crucial to avoid creating a "green moral hazard. This can be done by considering the long-term implications of actions taken and tackling the "right problem" (Wagner & Zizzamia, 2022). Green moral hazard occurs when technological solutions to environmental problems, like carbon removal or solar geoengineering, unintentionally cause harmful behaviors to persist by masking negative effects without tackling the root causes. For example, carbon removal technologies in particular focus on removing $CO_2$ from the atmosphere instead of reducing its emissions. Clearly, such solutions alone cannot fully resolve climate change, as companies will not be incentivized enough to reduce their emissions. For this reason, technologies should not stand alone but be integrated within a broader and comprehensive sustainability strategy. A solution alone is not enough, because its difference is made by the context it is part of.

The findings highlighted that GIS plays a crucial role in enhancing transparency, systematically managing environmental performance, and advancing sustainability within supply chains and product design: through it, other strategies can be carried out. However, the extent and effectiveness of the application of GIS varied significantly among the companies studied. It was reflected in different levels of readiness and integration, with some companies having most likely very basic system, and others having advanced systems that integrate artificial intelligence tools (Company I). In general, most companies still do not have an efficient Green Information System to help them in their sustainability goals, and even if some rely on good-quality, external ones made for this purpose, the potentiality of this instrument is still unexplored.

About the specific sustainability strategies, sustainable supply chain management is particularly challenging due to the global and intricate nature of supply networks of the high-tech industry. Obtaining reliable sustainability data from suppliers beyond Tier 1 remains challenging due to both the complexity of these supply chains and the intricate nature of high-tech products. Although

companies typically utilize third-party platforms like EcoVadis or IntegrityNext to assess ESG performance, current data processing and data verification methods remain relatively basic. This suggests considerable potential for improvement through emerging technologies such as blockchain and AI-driven analytics. Additionally, the research identified a strong need for companies to enhance supplier engagement, for example by incorporating sustainability criteria directly into contracts and offering incentives or support to improve compliance. However, effectively extending these practices beyond direct suppliers - particularly in regions with lower sustainability standards, like the ones in which the companies' source - remains a significant challenge. Indeed, it emerged that legislation greatly supports sustainability strategies, and where regulatory support is lacking, imposing sustainability clauses becomes much more challenging.

## 8.1 Limitations of the Research

Several limitations affected the reliability and scope of this study. Firstly, the small sample size, comprising only seven companies, significantly limits the generalizability of the findings. Also, the companies have been selected and interviewed for purposes other than this thesis, making it difficult to expand on certain aspects. For instance, it was not possible to fully apply the UTAUT method presented in the first chapter.

Another limitation arises from the delay between data collection and analysis. In fact, the interviews were carried out one year earlier the research. Given the rapid pace of innovation in sustainability practices and information systems, certain insights might already be outdated. The inconsistency in interview content, with varying questions posed to different companies, led to uneven thematic coverage. This made it difficult to determine whether the differences observed were due to actual variations in company priorities or simply resulted from the different questions asked. Lastly, the study relied heavily on qualitative analysis for the nature of its data source, introducing potential interpretation biases. In fact, the quantitative data collected was limited, and also based mainly on self-reporting, carrying the inherent risk that companies may present themselves as "greener" than they actually are.

## 8.2 Recommendations for Industry and Policymakers

On the private side, to overcome the challenges outlined above, businesses need to invest in both technology and people. Specifically, they should prioritize the acquisition or development of green

information systems. On them, they could build advanced data-management tools, such as blockchain solutions or AI-driven analytics platforms, to improve the accuracy, traceability, and verification of ESG information across their supply chains. At the same time, they should build the in-house expertise to use these tools effectively, interpret the results, and integrate them into decision-making processes.

It is also crucial for companies to collaborate. For this reason, engaging suppliers proactively can help address the root causes of poor data quality and low transparency. This could be done by sharing best practices, offering incentives for compliance, and support in the implementation of green actions. To do that, companies, especially the ones with an higher contractual power, need to establish clear contractual requirements.

At the same time it is necessary to develop and adopt internationally recognized technical standards for environmental and social metrics. Policymakers should work to harmonize existing guidelines, creating what is referred to as "technical standards". In this was, organizations worldwide could use compatible definitions, methodologies, and metrics when measuring their sustainability performance: this would remove much of the uncertainty and the work in cross-border comparisons and reduce the burden on companies required to comply with divergent rules or to interpret differencies.

Only when innovation is paired with shared values, transparent metrics, and it is supported by the right policy, sustainability become a real cornerstone of business strategy in the high-tech sector.

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