Sustainable strategies in energy-intensive industries: a qualitative study[1]

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Abstract

Frame of the research: *Sustainability has emerged as a strategic lever, particularly crucial for energy-intensive companies in the upstream level of supply chains, addressing resource scarcity and complexity while upholding sustainability goals.*

Purpose of the paper: *The study delves into how energy-intensive companies manage sustainable goals through circularity and supplier relationships.*

Methodology*: The research employs a qualitative approach with multiple case studies, including semi-structured interviews, due to its exploratory nature.*

Findings*: The results reveal that energy-intensive companies tackle sustainability challenges through product and process innovations, delineating four main approaches. Additionally, a conceptual matrix for sustainable strategies is developed.*

Research limits: *While a multiple case study offers insights, it is constrained by the number of actors involved. Increasing the number of interviews and collecting data from other actors alongside the supply chain would allow a broader perspective. Quantitative research could enhance result generalizability, and comparative analyses could spotlight cross-country similarities or differences, extending the analysis beyond Italy.*

Practical implications: *Evidence from case studies offers valuable insights for practitioners and companies, helping them identify key sustainable approaches and strategies. The study outlines four main strategic pathways for energy-intensive companies, providing managers with a roadmap for integrating sustainability principles into their organizational practices.*

Originality of the paper*: The paper is one of the few exploring sustainable strategies for energy-intensive companies, focusing on product and process innovations. It enhances sustainability discipline and marketing practices, adding to circularity and business relationship literature. It offers empirical evidence, detailing four main approaches and strategies to strengthen sustainability commitments*

Key words: *sustainability; innovation; business relationship; marketing strategy; industrial symbiosis*

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1. Introduction

In today's competitive environment, a commitment to sustainability has become a strategic imperative (Hunter and De Giacomo, 2023). This is particularly crucial for energy-intensive businesses, given their significant impact on the development of the nations in which they operate (Litvinenko *et al.*, 2022). Recognizing the importance of sustainability and its underlying principles, the three pillars-economic, social, and environmental-have been incorporated into the 2030 Agenda for Sustainable Development. This agenda serves as an action plan, highlighting the necessity for transitioning toward a responsible and sustainable economy. It garnered signatures from the governments of all 193 UN member states in September 2015, and was further reinforced at the Climate Change Conference (COP27) in 2022 to ensure sustainability for people, the planet, and prosperity (MASE, 2024).

A multitude of factors contribute to the increasing complexity of today's manufacturing environment. Firstly, the pandemic severely disrupted global supply chains and operations, causing significant financial losses for businesses worldwide (Cucari *et al.*, 2023). A period of recovery ensued, albeit hindered by shortages of intermediate goods and raw materials, leading to substantial price hikes across various industries (Paul *et al.*, 2021). Additionally, the conflict in Ukraine and uncertainties surrounding economic policies have resulted in an unstable market for raw commodities and pricing (OECD, 2024).

Companies operating in energy-intensive industries, such as aluminum, cement, ceramics, paper, steel, and wood, play pivotal roles in this context due to their connections to several major issues facing the modern business environment, including price increases, resource scarcity, business uncertainty, and sustainability concerns. Notably, the latter point has gained increased significance over the past decade (Litvinenko *et al.*, 2022). This study focuses on energy-intensive businesses at the upstream level of the supply chain, particularly by examining how they address resource scarcity and pursue sustainable goals through product and process innovations, with a focus on circularity and supplier relationships.

Concerning the first aspect, circularity pertains to how company operations are structured, emphasizing the recycling of waste or semi-finished products both internally and externally. A number of studies have explored how industrial companies integrate environmental, social, and economic principles-associated with the 2030 Agenda-into their operations to achieve circularity goals. According to Ma *et al.* (2023), enhancing energy-intensive manufacturing organizations' commitment to sustainable production involves addressing environmental, social, and economic challenges. Notably, characteristics such as high production intensity, complex multi-workshop simultaneous and asynchronous production, high pollution, and significant energy consumption typify energy-intensive manufacturing enterprises (Ma *et al.*, 2023). Even though circularity is a well-known topic, the literature highlights that little attention has been paid to how circularity can be integrated into companies' strategies (Eikelenboom and de Jong, 2022). In fact, most academic contributions focus on short-term practices, and it remains unclear how

circularity can be incorporated into the overall long-term strategies of companies (Ormazabal *et al.*, 2018). Although managers' views on the circular economy are evolving, it is uncertain whether and how this will translate into the integration of circularity into business strategies (Liu and Bai, 2014; Rizos *et al.*, 2016).

Regarding supplier relationships, all industry stakeholders strive for a better understanding of sustainable practices, with the importance of these relationships being paramount, especially for manufacturing firms heavily reliant on energy. Their supply chain places a strong emphasis on value generation, necessitating the development of new goods that meet sustainability standards and a reassessment of established processes involving new stakeholders (Amarasinghe *et al.*, 2024). Collaborative initiatives among businesses lead to the creation of new relationships and supply networks, wherein innovative methods or resources-such as energy, materials, information, or a combination thereof-are shared, even transcending the boundaries of a single industry. Although scholars recognize the importance of supplier relationships in achieving sustainable goals, little research has been conducted on how actors' relationships enable value creation for businesses and stakeholders under a common sustainable strategy (Tapaninaho and Heikkinen, 2022). In fact, while the literature emphasizes that companies should be aware that sustainability challenges cannot be addressed by one actor alone, further research must explore how business actors and stakeholders can engage in joint value-adding endeavors, going beyond the single firm perspective (Seuring and Gold, 2013).

Thus, this study is grounded in the emerging stream of literature on sustainable strategies, merging two main aspects that require further attention: circularity and supplier relationships. Consequently, this article aims to explore the innovative strategies implemented by energy-intensive companies to achieve sustainable goals through circularity and supplier relationships. Our research was guided by the following question:

RQ. How are energy-intensive companies managing sustainability objectives through innovative strategies leveraging circularity and relationships with suppliers?

This paper answers the research question through qualitative research on energy-intensive companies. It examines how these companies achieve sustainability goals via product and process innovations. The study identifies four main approaches based on circularity and supplier relationships, and introduces a conceptual matrix for sustainable strategies.

2. Theoretical background

Sustainability is a conceptual approach that pertains to the optimal utilization of existing resources to meet future demands (Greenland, 1997).

The Brundtland Commission provided the most widely accepted definition, describing sustainability as *"development that meets the needs*

of the present without compromising the ability of future generations to meet their own needs" (Brundtland, 1987). Sustainability entails utilizing both financial and non-financial resources to achieve social, economic, and environmental benefits (Farooq *et al.*, 2024). To effectively manage and balance these three pillars, Elkington (1998) introduced the "Triple Bottom Line" model of sustainability for organizations. Social sustainability aims to preserve social capital for societal advancement, safeguarding the environment and enhancing people's safety and quality of life (Sanders and Wood, 2024). Economic sustainability refers to an economy's ability to maintain a reasonable level of expanding gross domestic productivity or capital stock over an extended period (Rashid *et al.*, 2024). Environmental sustainability focuses on societal development that protects the ecological system (Bibri *et al.*, 2024).

Over time, the concept of sustainability has been applied in various fields, gaining increasing importance with the emergence of new technologies, and requiring new models to facilitate waste recycling and management by companies. Moreover, sustainability is intricately linked to the inclusion of various actors due to the business relationships established during production processes. This implies a systematic exploration of three main aspects-product and process innovation, circularity, and relationships with suppliers-to better comprehend the dynamics and strategies between companies when planning long-term sustainable strategies. In the following paragraphs, each aspect is presented and analyzed in detail.

2.1 Product and process innovation toward sustainability

Product development and process management play crucial roles in society's transition toward sustainability (Lu *et al.*, 2024). In the literature, innovation has been examined/investigated based on its diverse drivers, dimensions, and outcomes (Crossan and Apaydin, 2010). Among these outcomes, "product innovation" and "process innovation" characterize the introduction of new or improved goods and services, as well as enhancements in production methods (Babina *et al.*, 2024). The distinction between product and process innovation often stems from the assumption that their economic and social impacts may differ.

"Product innovations" involve initiatives aimed at introducing new goods or services to the market, with initial studies focusing on the environmental aspects of product design in the 1990s. Early research explored methods such as "green design" or "eco-design" to establish theoretical foundations for sustainable design (Bath, 1993). Recent studies on sustainable products emphasize methods and tools for improved design, highlighting the reduction of negative environmental impacts. However, the major effort was devoted to framing product innovations primarily focused on recyclable materials or green products, with limited consideration for social and economic perspectives. Only with the increasing recognition of sustainability as an integrated approach covering all three pillars did studies start to include analyses of product life cycles and supply chains (Gmelin and Seuring, 2014), though few fully address

all three sustainability pillars during the product innovation process (Wang and Su, 2022).

"Process innovations" consider initiatives which can include new production and distribution methods (Baptista, 1999). This encompasses envisioning new work strategies, innovative process designs, and complex technological, human, and organizational changes (Damanpour and Aravind, 2006). Process innovation offers significant potential for cost or time reductions, as well as improvements in quality, flexibility, and service levels (Davenport, 1993). Companies assess the demand for improved environmental performance activities, estimating associated costs and benefits to achieve environmental sustainability outcomes (Gui *et al.*, 2024). There is empirical evidence linking environmental performance to financial performance, suggesting that firms *"do well by doing good"* (Ambec and Lanoie, 2008), highlighting the need for a holistic sustainability model. Firms frame environmental improvement in terms of resource productivity, focusing on the opportunity costs of pollution-wasted resources and effort, and diminished product value (Porter and van der Linde, 1995). Companies tend to adopt environmental management practices that complement business and corporate-level strategies to enhance profitability or shareholder wealth. Hence, firms innovating in processes improve efficiency and performance (Costa-Campi *et al.*, 2015).

2.2 Circular economy and Circularity

The concept of the Circular Economy finds its origins in the late 1970s (EMF, 2013; Ghisellini *et al.*, 2016). Initial attempts at conceptualization were based on the linear and open-ended characteristics of society, evolving toward a closed and circular system where process wastes serve as inputs for other activities.

The most widely recognized definition comes from the Ellen MacArthur Foundation, describing the Circular Economy as "an industrial economy that is restorative or regenerative by intention and design" (EMF, 2013, p. 14).

The Circular Economy has garnered attention over the years and has been applied in various fields such as supply chain management and business models (Govindan *et al.*, 2018). Contemporary understanding of the Circular Economy involves reusing someone else's waste to create something new (Geissdoerfer *et al.*, 2017). Even though circularity has gained traction among industries, researchers, and policymakers due to its implications for reducing resource use, waste, and emissions in the short term (Geissdoerfer *et al.*, 2017), scholars underline that little attention has been paid to how circularity can be integrated into the overall long-term strategies of companies (Eikelenboom and de Jong, 2022; Liu and Bai, 2014; Ormazabal *et al.*, 2018; Rizos *et al.*, 2016).

Experts and practitioners view circularity not only as a desirable option but also as a critical aspect for attaining a competitive advantage. Shifting from a conventional and linear business model to a circular one poses significant challenges for businesses. The supply chain must be productive and efficient to implement this circular perspective (Pomponi

and Moncaster, 2017). Thus, the discussion often revolves around the circular supply chain, where resources enter an infinite loop of reuse, remanufacturing, and recycling, promoting the continuous flow of products back into productive systems (Genovese *et al.*, 2017).

To transition from a conventional to a circular supply chain, the concept of "keeping in the loop longer" or extending the lifespan of materials is crucial (EMF, 2013). Collaborative initiatives aimed at prolonging product lifespans and repurposing materials beyond their initial use for repair and recycling are essential (De Angelis *et al.*, 2018).

2.3 Sustainability and relationships with suppliers

Collaboration and relationships with suppliers are essential, particularly when the primary objective is achieving sustainable goals. Various scholars have attributed collaboration different advantages (Dubey *et al.*, 2019). For instance, from an economic standpoint, collaboration among companies leads to cost savings in sourcing, avoidance of disposal costs, and/or additional profits from selling by-products, thereby improving organizational performance (Vachon and Klassen, 2008). Furthermore, environmental benefits associated with collaboration include reduced consumption of natural resources, waste reduction, and decreased emissions to air, water, and soil (Chertow and Lombardi, 2005).

Collaboration is regarded as an enabler of superior performance in firms by capitalizing on resources, capabilities, processes, and routines existing within partner firms (Fawcett *et al.*, 2015). It is essential for internal integration to enhance an organization's efficiency in supply chain activities (Simatupang and Sridharan, 2002). Examples of organizational collaboration include shared environmental planning (Ghisellini *et al.*, 2016), joint efforts to reduce pollution and use resources efficiently, and setting common environmental goals (Daniels and Walker, 2001) to achieve environmental sustainability across the supply chain.

However, implementation can be challenging, as there may be difficulties in understanding when and with whom to collaborate (Romito *et al.*, 2023). In addition, the literature underscores the scarcity of research on how businesses and stakeholders can create value under a common and long-term sustainable strategy (Seuring and Gold, 2013; Tapaninaho and Heikkinen, 2022).

Moreover, lack of trust between partners may hinder collaboration (Barratt, 2004). For this reason, companies sometimes seek collaboration with suppliers outside the boundaries of their own sector. By engaging in cross-sector collaborations, companies can tap into a broader pool of resources, expertise, and opportunities for synergistic partnerships. Cross-sector collaborations enable companies to access resources and capabilities that are not readily available within their own industries. This fosters innovative solutions and novel approaches to sustainability challenges. The exchange of resources and practices among business networks creates new interconnections that companies must effectively manage (Demartini *et al.*, 2022).

3. Methodology

Due to the exploratory nature of the research question, a qualitative approach is employed through a multiple case study. This methodology is particularly valuable for empirical inquiry into contemporary phenomena, enabling the exploration of under-studied topics (Yin, 2018) and facilitating comparisons among different cases (Pauwels and Matthyssens, 2004). Additionally, we aim to address a gap in the current literature, which advocates for modeling efforts with stronger empirical foundations and more robust attempts at real-world validation (MahmoumGonbadi *et al.*, 2021).

The methodological approach follows Yin's (2018) framework and is divided into three main phases:

1) Define and design: theory development, case selection, and design of data collection protocol.
2) Prepare, collect, and analyze: research, collection, and analysis of data from case studies.
3) Analyze and conclude: development of cross-case conclusions, redefinition of theory, and identification of policy implications.

For this research, ten cases are included. As affirmed by Eisenhardt (1989), the appropriate number of cases for multiple case study research ranges between 4 and 10. The selection of case studies was based on a thorough exploration of each energy-intensive sector (aluminum, cement, ceramics, paper, steel, and wood), focusing on identifying the most representative companies and/or associations. This dual perspective provides a broader and more focused analysis of the topics under investigation. The main criteria for inclusion are:

i) Company Case Study:
   - o Industry Leader: The chosen company holds a substantial market share and has established itself as the/a leading player within its sector.
   - o Virtuous Company: The selected company has received awards for sustainable practices or has documented and demonstrated a specific commitment to sustainability through successful projects and activities.

ii) Association Case Study:
   - o Point of Reference: The chosen association operates in Italy and serves as a key actor and reference point for companies in the identified sectors.

The selection of participants, guided by theoretical sampling criteria (Glaser and Strauss, 2017), focused on their expertise in sustainability and marketing practices to ensure a wide range of insights and relevant experience related to the phenomenon under investigation (Richards *et al.*, 2009).

The interview was chosen as a data collection technique, as widely employed in case studies (Seuring, 2008). This method facilitated the acquisition of information through face-to-face verbal and non-verbal exchanges, enabling a deeper understanding of the interviewees' perspectives (Rowley, 2012). The content of the semi-structured interviews

was derived from the literature review and focused on three main sections:

- Sustainability areas of interest and circularity practices;
- Product and process innovations implemented for sustainable purposes;
- Supplier relationships and business networks toward sustainability strategies.

To minimize the risk of biased responses, the interviewer presented the study goals and emphasized that all answers were equally acceptable. The clarity of questions was ensured through a pilot interview to receive feedback and suggestions. In total, 10 interviews were conducted via videoconference between January and June 2023, ranging from 45 to 120 minutes each (Table 1) for a total duration of approximately more than 11 hours. All conversations were recorded and transcribed, with subsequent verification and confirmation by each interviewee.

Tab. 1: Case studies and informants

Sector	Case study	Description	Role of informants	Duration of the interview
Aluminium	1. Company-Case Study: RAFFMETAL 2. Company-Case study: LAMINAZIONE SOTTILE 3. Association- Case study: ASSOMET	1. Since 1994 Raffmetal has achieved a 100% continuous casting production. It produces aluminum by recovering goods that have exhausted their life cycles, giving them new value. 2. Laminazione Sottile produces aluminum laminates in various alloys and sizes for sustainable and long-lasting development, translating them into constant attention to the environment, safety and health of employees. 3. Founded in 1946, it is the national association representing producers and processors operating in the non-ferrous metal industries	1. ICSR manager 2. CEO 3. Environment Manager	1. 50 min 2. 60 min 3. 45 min
Cement	1. Company-Case study: ITALCEMENTI	1. For over 150 years Italcementi has been a leader in the building materials sector, offering innovative, sustainable and quality products to provide integrated solutions.	1. Eco-brand manager	1. 45 min
Ceramic	1. Company-Case study: FLORIM 2. Association-Case study: CONFINDUSTRIA CERAMICA	1. Florim, a company founded in 1962 in the ceramic district of Sassuolo (MO), is a leader in the ceramic industry with social and environmental responsibility. 2. Founded in 1964, Confindustria Ceramica is the association that represents, connects, informs and assists Italian manufacturers of ceramic tiles, refractory materials, sanitary ware, tableware and ceramics for industrial use.	1. Communication director 2. 2 Managers: Economic department and Sustainability department	1. 90 min 2. 45 min
Paper	1. Company-Case study: FAVINI 2. Association-Case study: ASSOCARTA	1. Favini, founded in 1736, is a historic paper mill committed to the search for alternative raw materials to tree cellulose and the creative use of waste materials. 2. Assocarta, established in 1888, is the trade association that aggregates, represents and protects companies that produce paper, cardboard and paper pulp in Italy	1. Marketing manager 2. President	1. 90 min 2. 90 min
Steel	1. Company-Case study: MARCEGAGLIA	1. Founded in 1959 in Gazoldo degli Ippoliti (MN), Marcegaglia is the leading Italian industrial group in the entire steel value chain from its production. 2. Federacciai, the Federation of Italian Iron and Steel Companies, was established on 16 December 1988 from the merger of three major industry associations to create a single federal body	1. Sustainability manager	1. 45 min
Wood	1. Company-Case study: MARLEGNO	1. Marlegno has been in the sector of large wooden buildings and houses since 2000, guided by the principles of the circular economy	1. CEO	1. 120 min

Source: our elaboration

The methodology employed in this study is based on recommendations by Lindgreen *et al.* (2021), which enhances the validity of the discussion in terms of replicability (Yin, 2018). This approach is commonly adopted to investigate the empirical implications of the literature of reference (Yin, 2018). Specifically, four criteria were applied to assess the validity and reliability of this approach (Table 2) (Lindgreen *et al.*, 2021).

Tab. 2: Assessment of validity and reliability

Criteria	Theoretical aim	Operative tactics
Construct validity	Correct operational measures of studied concepts	• Triangulation: o multiple methods: interviews, case feedback from respondents o multiple data sources: primary data (interviews) and secondary data (firm's web pages, archival materials, reports, articles) • Chain of evidence: recording and transcription of all interviews, providing a chain of evidence
Internal validity	Causal relationship	This concept was not addressed because the study was exploratory
External validity	Relevance of findings	• Specification of population of interest: selection of a number of cases in line with Eisenhardt (1989) • Identification of inclusion criteria: selection of the cases respectful of specific criteria • Replication logic: use of a standardized interview protocol
Reliability	Replicability of findings following procedures	• Interview protocol: development of a standardized interview guide • Inclusion criteria: identification of specific requirements for: o Company Case Study: Industry Leader and Virtuous Company. o Association Case Study: Point of Reference: • Clearly conceptualized concepts: creation of the interview guide based on the literature review • Execution of a pilot test: conduction of a pilot interview before the main data collection phase • Triangulation: collection of primary data (interviews) and secondary data (firm's web pages, archival materials, reports, articles)

Source: our elaboration based on Lindgreen *et al.* (2021) and Yin (2018).

4. Findings

This section presents findings from semi-structured interviews with energy-intensive companies, focusing on sustainability goals (economic, social, environmental) aligned with the Agenda 2030. The results discuss the initiatives undertaken by these companies, including changes, integrations, and modifications in their strategies related to product and process innovations.

Overall, it is evident that companies are addressing sustainability issues through both product and process innovations. "Product innovations" refer to initiatives aimed at introducing new goods or services to the market, while "process innovations" involve implementing new methods of production and distribution of goods.

Moreover, these types of innovations are achieved through both internal activities, such as research and development conducted within the

company, and external activities that involve stakeholders outside of the company's operations for implementation.

4.1 Product Innovation

Product innovation plays a pivotal role in the strategy of sustainability-oriented businesses. The following section delves into the intricate activities undertaken both within and outside companies to drive product innovation, with a particular emphasis on integrating sustainable practices.

Within corporate boundaries, Research and Development (R&D) activities stand as the cornerstone of product innovation. This essential function allocates substantial resources to enhance the attributes of existing products and conceive new solutions, thereby infusing the production cycle with a sustainability-oriented perspective. For instance, Marcegaglia Group has embarked on a journey toward "green steel", initiating an internal process to reevaluate product design by evaluating raw material sourcing and the environmental footprint per ton of product from a sustainable standpoint. Similarly, Heidelberg Materials, under the guidance of its Sustainability manager, has introduced various sustainable products aimed at reducing CO2 emissions. The manager further specifies that *"to reinforce internal commitment to sustainable products, it has been mandated that 50% of products introduced to the market by 2030 must contain significantly recycled content"*. This underscores a broad commitment to minimizing the environmental impact of production, advocating for renewable energy sources, and reimagining product design with sustainability at its core, including the utilization of by-products from other industries without compromising product quality.

Moreover, internal investments in new technologies represent another critical pillar for developing sustainable products. The CEO of Favini states that *"investing in sustainability is now imperative. To drive product innovation, it is essential to undertake R&D activities that entail costs with medium to long-term returns"*. In alignment with this vision, Marcegaglia Group has made substantial investments in establishing Europe's first green steel factory.

Continuous monitoring of product innovation is a widely adopted practice. The CEO of Marlegno emphasizes the necessity of investing in internal activities to monitor product innovation, with a focused approach on reducing environmental impact in terms of CO2 emissions. This analytical process not only evaluates the efficacy and performance of initiatives but also scrutinizes sustainability metrics. Through ongoing analysis, companies can make targeted adjustments, ensuring consistent alignment with corporate goals and those outlined in the Agenda 2030.

Externally, product innovation is closely intertwined with collaborative networks. Collaboration with suppliers assumes a central role in enhancing product sustainability. These partnerships entail proactive efforts to explore eco-friendly materials and adopt sustainable production processes, thereby promoting responsible sourcing and overall environmental footprint reduction. Given the nature of its paper production process (mainly water and cellulose), Favini actively seeks new suppliers of by-products suitable for cellulose extraction. Additionally, aiming to enhance

product characteristics, Florim's Sustainability manager emphasizes that *"sustainability entails not only conducting commendable activities independently but also raising awareness among supply chain participants that [if it is companies] contribute to product realization through raw materials"*.

Furthermore, certification bodies play a pivotal role in ensuring compliance with sustainability standards. Products meeting specific requirements and characteristics can effectively underscore a company's sustainable approach to external stakeholders. Through close collaboration, companies can conduct thorough analyses, tangibly demonstrating their commitment to sustainability and establishing a credible basis for communication with consumers. In the ceramics sector, representatives from Confindustria Ceramica highlight the introduction of specific certifications for ceramic products in certain export markets, signaling a commitment to sustainability. However, achieving this requires closer collaboration with associations, institutions, and universities, as there is an ongoing debate regarding the appropriate parameters to define the level or criteria of product sustainability. These collaborative initiatives, leveraging specialized expertise and shared resources, have the potential to contribute across industries by defining indicators, variables, and parameters essential for determining the degree of product sustainability.

Finally, interviews emphasize the indispensable role of customer engagement in advancing the sustainability of products. Companies can foster an active dialogue with customers, gathering valuable feedback that fuels innovation and effectively communicates the new sustainable attributes of products. This communication not only cultivates customer loyalty but also opens doors to new market opportunities.

4.2 Process Innovation

Within the company, process innovation manifests through several initiatives. Firstly, investing in new technologies emerges as a strategic lever, integrating digital solutions and advanced technologies to boost efficiency and overall sustainability in business operations.

From this perspective, Heidelberg Materials highlights that their furnaces and cement plants currently rely on fossil fuels. To elevate the sustainability of their products, investing in new technologies is crucial to achieving a progressive reduction in CO2 emissions, potentially up to 400 kilograms per ton of cement-a 50% reduction compared to values from the 1990s. Similarly, companies like Marcegaglia and Florim are exploring investments in new technologies aimed at identifying alternative sources such as hydrogen. However, as noted by Florim's Sustainability Manager, *"while hydrogen represents a promising new energy source for production cycles, further assessments are needed to determine its effective and sustainable integration into production systems"*.

Simultaneously, enhancing internal policies plays a decisive role. Through targeted training programs, companies invest in cultivating a sustainability-oriented corporate culture. Marcegaglia Group argues that *"internal training and the development of robust corporate policies foster a workforce more inclined toward sustainable practices, leading to overall*

improvements in processes and corporate sustainability. This shared objective enhances efficiency from both economic and social perspectives". Continuous training and the reinforcement of internal policies contribute to creating an environment where sustainable process innovation becomes ingrained in the corporate identity.

The next crucial step, as highlighted in interviews, involves transitioning toward circularity. Reassessing and reshaping production processes to embrace circular models becomes imperative. This approach entails recycling, reusing, and designing products that support repair, thereby promoting more sustainable resource management.

For example, Florim has implemented a fully automated corporate plant with redesigned processes aimed at minimizing human involvement in risky operations, leveraging Industry 4.0 technologies. Covering 10,000 square meters and employing only 8 staff members, the plant primarily produces make-to-stock products. In the context of circularity, Heidelberg Materials has re-envisioned aspects of its cement production process to reduce CO2 emissions by reintroducing pollutants directly into the process via a piping system.

Similar to product innovation, achieving process innovation necessitates a robust network of relationships with external actors. Of particular significance is the relationship with suppliers, encompassing both existing and potentially new partners. Collaborating closely with current suppliers becomes a fundamental strategy to ensure alignment with sustainability requirements across the supply chain.

For instance, Florim administered a questionnaire to its suppliers to verify adherence to sustainable practices in raw material production processes. Through strong partnerships, companies can implement shared and synergistic practices, including the development of circular processes aimed at reducing environmental impact. A notable example is Favini, which collaborates closely with its suppliers to close water cycles and reuse water from production processes, thus conserving water.

Engaging new suppliers introduces an element of radical innovation. Again, in Favini's case, leveraging suppliers is crucial for developing collaborations with companies beyond traditional business activities. These collaborations involve converting by-products through chemical processes into valuable cellulose required in the paper production process, thereby extracting valuable raw materials from simple waste. Such collaborations can spur the introduction and development of new processes through cooperation with stakeholders from diverse sectors, promoting a model of industrial symbiosis.

Moreover, close collaboration with associations, institutions, and universities presents opportunities to facilitate the development of new technological and innovative processes geared toward sustainability. Additionally, these partnerships can provide access to financial incentives for the development of innovative and sustainable projects.

Customer engagement is of critical significance to make new production processes both tangible and relevant. Communicating with customers about new sustainable practices and fostering brand awareness tied to innovative and sustainable processes facilitates the enhancement of

customer loyalty while also attracting new clientele interested in cutting-edge sustainability practices.

Process innovation entails a complex interplay of internal and external actions, demanding a synergistic approach to achieve substantial progress toward corporate sustainability. The amalgamation of internal and external strategies serves to redefine business processes, steering them toward more efficient resource management and contributing to the pursuit of sustainability goals outlined in the Agenda 2030.

5. Discussion

As highlighted in the preceding section, energy-intensive industries, with a growing emphasis on sustainability, are implementing various strategies to mitigate environmental impacts and advance responsible practices. Interviews with companies have identified six key strategies that serve as fundamental pillars in this regard, summarized for clarity in Table 3.

Firstly, numerous companies are prioritizing the development of sustainable relationships with suppliers. This extends beyond conventional commercial transactions to actively promote high ethical and environmental standards among suppliers. The goal is to establish more sustainable supply chains that foster social responsibility across the value chain and decrease the overall environmental footprint of business operations.

Tab. 3: Companies attention areas to sustainability

Relationship with suppliers	Some companies prioritize developing sustainable supplier relationships by promoting high ethical and environmental standards or implementing more sustainable supply chains.
Circularity	Circularity, the reuse and recycling of materials, is a priority for some companies. They actively seek to reduce waste and maximize resource efficiency in their processes.
Carbon Footprint reduction	Many companies have placed carbon footprint reduction at the centre of their sustainability strategies. This involves transitioning to renewable energy sources or adopting low-carbon practices and technologies.
New technologies	Many companies pay special attention to new technologies to monitor and identify new sustainable energy sources, although these technologies are still being studied.
Internal company policies	Some companies are creating detailed corporate sustainability policies to promote sustainability across all organizational levels. These policies set goals, assign responsibilities, and outline procedures for integrating sustainability into business operations.
Attention to social landscape	Some companies demonstrate strong attention and commitment to their operating territories through corporate social responsibility initiatives, community projects, or local development efforts, thereby enhancing the local value.

Source: our elaboration

Simultaneously, circularity represents a priority for some companies actively seeking to reduce waste and enhance resource efficiency through

material reuse and recycling. This practice not only contributes to the mitigation of environmental impacts but also facilitates the emergence of new business opportunities by fostering more sustainable and resilient economic models.

Reducing the carbon footprint is another crucial element in sustainability strategies. Many companies have positioned this objective at the forefront of their agendas by transitioning to renewable energy sources, adopting low-carbon technologies, and implementing practices to improve overall energy efficiency. These measures decrease pollution while also bolstering corporate resilience in the face of climate challenges.

The adoption of new technologies, such as hydrogen, holds significant promise as companies explore innovative and sustainable energy sources. While still in the exploratory phase, these technologies have the potential to revolutionize the energy landscape by offering solutions to reduce reliance on non-renewable resources and diminish the environmental impact of industrial operations.

Internal corporate policies represent a critical aspect in advancing sustainability goals. Some companies are developing clear and comprehensive policies aimed at embedding sustainability throughout all levels of the organization. These policies establish specific goals, delineate responsibilities, and outline procedures for integrating sustainability into daily business operations, thereby fostering a culture oriented toward sustainability.

Lastly, some companies demonstrate a robust commitment to the communities where they operate. This commitment is evident through corporate social responsibility initiatives, support for community projects, and efforts to promote local development. By contributing value to the community, these companies enhance their social standing and contribute to the well-being of the communities they serve, promoting a more integrated and sustainable approach overall.

5.1 Circularity and Supplier Relationships

In light of the insights summarized in Table 3, it is crucial to systematically organize these points, particularly focusing on two prominent trends highlighted during the interviews and considered pivotal in the sustainability strategies of the interviewees: circularity and supplier relationships.

Viewing sustainability through the lens of circularity within the production process transcends mere aspiration; it is now an imperative necessity for energy-intensive industries. Circular practices embody the highest application of environmental and ethical principles, permeating the entire value chain. These practices can be categorized into four key strategies as identified through interviews.

Firstly, the strategy of developing internal waste management practices demonstrates a tangible commitment to integrating recycling into production processes. This involves establishing internal systems for collecting, disposing, and recycling materials, thereby not only reducing waste but also enhancing overall business efficiency, with substantial impacts on both environmental and economic sustainability. For example,

Heidelberg Materials has initiated closed-loop production initiatives that capture and reuse waste and by-products early in the production process, thereby minimizing the waste of reusable raw materials.

The second strategy involves adopting innovative production systems designed for the recycling of consumable materials. This marks a significant shift in production paradigms, as systems are designed with recycling in mind, thereby reducing environmental impacts and advancing companies toward more circular models that depart from traditional linear approaches and prioritize resource efficiency.

The third strategy focuses on integrating recycled raw materials into production processes, thereby reducing reliance on finite natural resources. Incorporating recycled materials promotes sustainable resource management while meeting the increasing demand from environmentally conscious consumers. A noteworthy example is Favini, which uses by-products from other industries to extract cellulose for paper production.

The fourth strategy emphasizes proactive product redesign to maximize lifecycle and facilitate recycling. This approach requires innovative design thinking to create products that align with sustainability goals, fostering a cultural shift in product conception within the industry.

To integrate these strategies into daily operations effectively, it is essential to assess the level of circular processes adoption. Utilizing a scale that measures the transition from linear to circular approaches provides a structured framework for evaluating a company's progress toward sustainability. Such assessments not only gauge efforts made but also serve as strategic tools to pinpoint areas for enhancement and optimization.

Turning to supplier relationships, their fundamental role in energy-intensive industries is evident, serving as a critical measure/instrument of the relationship's strategic orientation toward sustainability processes. These relationships transcend mere transactions, acting as strategic levers that influence the success of circular practices and overall sustainability commitment.

One approach to determining the depth of supplier relationships concerns direct supplier involvement. This entails fostering active collaboration between the company and its supply network, promoting transparency in operations and facilitating the sharing of sustainable goals and practices across the supply chain. Continuous dialogue with suppliers becomes crucial to identifying improvement opportunities and effectively implementing circular practices.

Furthermore, the contractual strength of the company plays a pivotal role. Companies with stronger negotiating positions can embed specific sustainability commitments into supplier contracts, thereby creating an environment that incentivizes the adoption of circular and sustainable practices among suppliers.

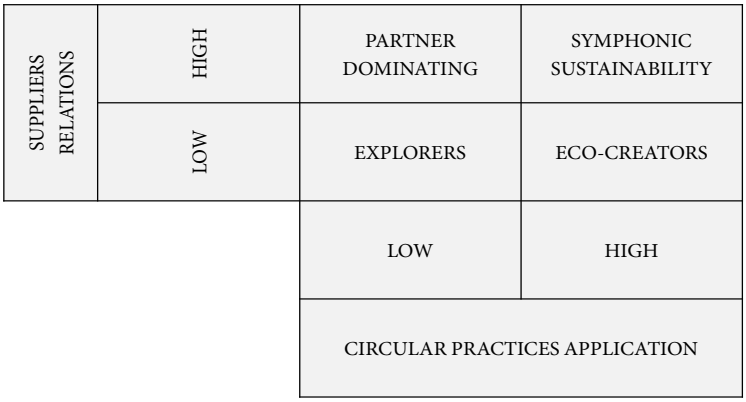
Finally, joint development practices with suppliers represent another crucial aspect. Collaborative initiatives involve jointly defining goals, strategies, and actionable steps to enhance sustainability across the supply chain. This approach encourages knowledge sharing and the co-creation of innovative solutions, fostering the widespread adoption of circular practices.

It is clear that supplier relationships are more than mere procurement processes; they are essential strategies for promoting circularity. Active engagement, bolstered by contractual influence and collaborative development practices, constitutes a strategic approach to achieving higher levels of sustainability across industries.

5.2 The Sustainability Positioning Matrix

In light of these observations, a matrix has been developed based on the determinants of supplier relationships and circularity, providing a comprehensive framework to understand how companies are integrating sustainable strategies. These four approaches reflect distinct stages of corporate maturity and commitment toward sustainability, allowing for the identification of possible sustainable strategies.

Fig. 1: Sustainability Positioning Matrix



Source: our elaboration

As observed in Figure 1, companies classified as "Explorers" represent a significant beginning in the journey toward sustainability. While perhaps not having yet established strong ties with suppliers or adopted advanced circular practices, these organizations are showing a growing interest in sustainability. They might have introduced internal policies and cultural changes, signaling a paradigm shift and an awareness of the importance of sustainability for their future. This exploratory phase embodies an initial stride toward understanding how to effectively integrate sustainability into their production processes.

Conversely, the "Eco-Creators" stand out for the advanced application of circular principles. These companies have not only internalized a strong sustainability culture but are also implementing innovative practices to optimize the life cycle of products. Their focus on recycling, reusing, and circular design demonstrates a tangible commitment to reducing waste and making a positive impact on the environment. Although supplier involvement may not be at the core of their strategy, their contribution to the circular economy is significant, offering an advanced perspective on sustainable resource management.

Companies classified as "Partner Dominating" excel in supplier relationships, a crucial element in achieving sustainable objectives. Managing strong and sustainable partnerships demonstrates their ability to influence and actively collaborate with the supplier network. While their focus is primarily on the supply aspect, their prominent role in procurement underlines their dominance in the industry. Although circularity may not be their forte, their influence in the supply chain positions them as key players in promoting sustainable practices within their industry.

Finally, "Symphonic Sustainability" represents the pinnacle of sustainable commitment. This term intends to evoke the concept of a symphony to represent an excellent combination of activities directed toward sustainability. Just as in an orchestra all instruments move in unison to create a perfect symphony, the seamless organization of productive process and relationship management enables the achievement of higher sustainability levels. A concrete example is the principle of industrial symbiosis, wherein companies manage their activities in a circular perspective to reduce internal waste while engaging with other market players to utilize their by-products or sell their own by-products, which thus acquire new value for these actors. In this process, named after the biological context, the companies, i.e. the symbiont, become so interconnected through commercial exchanges that they would no longer thrive without them, or, in the case of business strategies, would no longer be able to aspire to such high levels of sustainability.

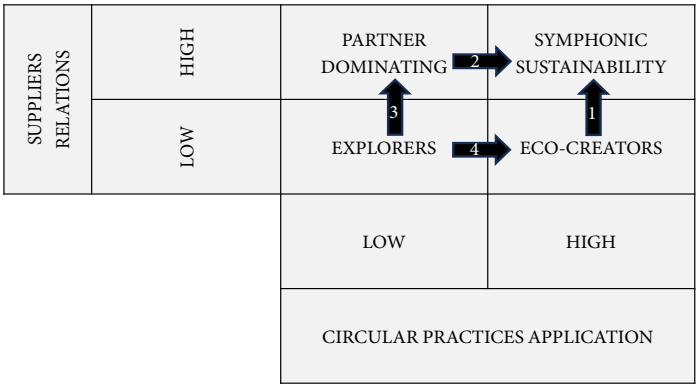
These companies stand out not only for extensive supplier involvement but also for strong partnerships grounded in sustainability-centered values. The adoption of innovative circular approaches, such as product recycling and design for reuse, highlights a long-term vision of sustainability. These companies continue to invest in new technologies, remaining at the forefront of sustainable practices; they are not just benchmarks but inspire other organizations to emulate their efforts, thereby promoting a shared vision of a sustainable industrial future.

5.3 Sustainability strategies along the matrix

Within the context of defining different positions within the quadrant, several strategic pathways are outlined to guide companies toward achieving higher levels of sustainability, ultimately aiming for the virtuous condition of industrial symbiosis. Each strategy presents a structured approach that can assist companies in establishing a sustainable and circular framework.

The first strategy (identified as 1 in Figure 2) focuses on engaging suppliers in circularity efforts through robust collaborative relationships. This necessitates close cooperation with suppliers to advance circularity principles and develop innovative solutions. Collaborative design of circular products and processes becomes pivotal, fostering resource and knowledge sharing through dedicated platforms. This approach not only minimizes waste but also identifies opportunities for improvement, fostering an environment where sustainability becomes a shared objective. Concurrently, innovating product designs with a focus on maximizing circularity and exploring new markets rooted in circular models promotes a comprehensive approach to sustainability.

Fig. 2: Sustainable strategies toward Symphonic sustainability



Source: our elaboration

As illustrated in point 2 of Figure 2, the second strategy centers on enhancing partnerships with suppliers. This approach entails deeper collaboration with existing suppliers, founded on clearly defined sustainability goals. In this case, establishing concrete objectives aligned with the overall strategy and consistently monitoring their progress are crucial components. Open communication and sharing of best practices reinforce these relationships, ensuring ongoing dialogue. Adopting circular strategies, such as designing products for recyclability and integrating recycled materials, further advances sustainability across the supply chain. Creating synergy with suppliers not only enhances overall sustainability efforts but also solidifies the company's reputation as a reliable partner in promoting sustainable practices.

The third strategy, depicted by arrow number 3 in Figure 2, emphasizes building partnerships with suppliers through active participation in defining sustainability goals and potentially integrating sustainability clauses into contracts. Strengthening relationships is based on collaborative initiatives that transcend mere transactions. Actively involving suppliers in setting shared goals fosters closer ties and encourages a collective commitment for sustainability. Concurrently, raising awareness and providing training for internal teams and suppliers alike becomes instrumental in ensuring widespread understanding of circularity's importance. This investment in training not only enhances overall awareness but also promotes collaboration and the adoption of circular practices.

Lastly, at point 4 of Figure 2, the fourth strategy focuses on embedding circularity within company operations. Central to this strategy is the adoption of circular practices, such as material recycling and product reuse. Integrating circularity into the company's operational strategy underscores a long-term dedication to sustainability. Actively involving suppliers in promoting circularity, through collaboration on initiatives such as material recycling, or jointly developing solutions to minimize waste, completes this strategy. This approach enhances operational efficiency while positioning the company as a pivotal advocate for circular practices along the supply chain.

6. Conclusion

The aim of this research is to explore the innovative strategies adopted by energy-intensive companies to achieve sustainable goals by leveraging circularity and supplier relationships. Qualitative research was conducted to identify four primary approaches toward sustainable practices, facilitated by two key determinants: circularity and supplier relationships. These approaches (Explorers, Eco-Creators, Partner Dominating, and Symphonic Sustainability) are visualized in a positioning matrix, illustrating how each energy-intensive company can progress along the matrix by employing different strategies to enhance their commitment to sustainability. The Symphonic Sustainability approach represents an endpoint characterized by high levels of circularity and supplier involvement in sustainable practices. This approach is closely tied to the concept of industrial symbiosis, emphasized in the literature as particularly crucial for energy-intensive industries.

6.1 Theoretical Implications

The study makes a significant contribution to the extensive and evolving literature on sustainable strategies and marketing practices, which have gained increasing importance in contemporary academic discourse. While sustainability has unquestionably risen in prominence over the past decade, with numerous scholars exploring its multifaceted dimensions (Litvinenko *et al.*, 2022), there remains a noticeable gap in understanding how energy-intensive industries can comprehensively integrate sustainable practices into their operations, particularly through product and process innovations. In effect, the literature indicates that only few contributions have focused on how to integrate circularity within companies' strategies (Eikelenboom and de Jong, 2022). In particular, it is not clear how circularity can be integrated in the overall long-term strategies of companies, beyond a short-term perspective (Liu and Bai, 2014; Ormazabal *et al.*, 2018; Rizos *et al.*, 2016).

In addressing this gap, the study unveils four primary strategies that energy-intensive companies can employ to meaningfully advance their sustainability goals. These strategies are not only differentiated by their varying levels of circularity but also by their degrees of supplier involvement, reflecting the nuanced and interconnected nature of sustainable business practices.

This analysis also sheds light on another research gap, namely limited investigation into how stakeholder relationships enable value creation for businesses and stakeholders under a unified sustainable strategy, moving beyond a singular firm perspective (Seuring and Gold, 2013; Tapaninaho and Heikkinen, 2022).

Central to our research is the development of a robust conceptual framework, derived from an extensive analysis of multiple case studies. The presented matrix elucidates a central theme in contemporary sustainability discourse: industrial symbiosis. Positioned as the apex, "Symphonic Sustainability" embodies the highest level of sustainable commitment

achievable by energy-intensive enterprises. Companies following this approach forge robust partnerships rooted in shared sustainability values and embrace innovative circular practices; their strategic vision prioritizes long-term sustainability goals over short-term gains.

At its core, "Symphonic Sustainability" envisions a collective pathway toward a sustainable industrial future characterized by mutual cooperation and symbiotic relationships among diverse industrial players. As emphasized by Fraccascia *et al.* (2023), cultivating such symbiotic partnerships represents a fundamental shift toward resilient and sustainable industrial ecosystems.

In recent years, industrial symbiosis has garnered significant attention due to its ability to leverage new advantages. Scholarly contributions highlight industrial symbiosis as a potent strategy for waste reduction and the cultivation of sustainable practices through circular economic systems (Kleinpeter *et al.*, 2024; Mortensen and Kørnøv, 2019). It effectively transforms wastes and by-products from one industry into valuable raw materials for another, thereby fostering resource optimization and sustainability (Boons *et al.*, 2017).

Our research not only reaffirms the critical role of industrial symbiosis in promoting sustainable business practices but also highlights its synergistic alignment with the diverse strategies outlined within our conceptual framework.

In conclusion, our study provides a comprehensive roadmap for energy-intensive companies navigating the complexities of sustainability. By embracing "Symphonic Sustainability" principles and cultivating collaborative relationships grounded in shared values, these companies can chart a course toward a more sustainable and prosperous future, benefiting both themselves and the broader industrial ecosystem.

6.2 Managerial Implication

Our research offers practical insights for companies and managers pursuing sustainable goals within energy-intensive industries. Recognizing the urgency of strategic action, the article explores the various strategies available to these companies to navigate the complex sustainability landscape. Drawing on insights and results derived from numerous case studies, it presents four key strategic paths accessible to companies in these sectors. The cases analyzed, given their relevance in the sector and documented sustainable virtuous activities, enable managers to glean insights into practices already implemented by leading companies. These can be taken as reference points and examples to structure concrete actions toward sustainability goals.

Furthermore, our study serves not only as a compendium of sustainable strategies, but also as a practical tool for companies aiming to improve their sustainability commitments. By identifying crucial strategies and offering practical recommendations, the article provides managers with a roadmap for effectively integrating sustainability principles into organizational practices. It presents potential paths to achieve a high level of integration between sustainability-oriented activities and relationship

management. Thanks to this, managers can discern their company's strategy and determine the most suitable direction for advancement based on an analysis of existing resources and relationship networks.

This approach enables managers to develop tailored strategies aligned with their company's goals, values and unique operating context, with a specific focus on advancing product and process innovations. In addition, our research encourages a deeper investigation of the dynamic interplay between circularity and supplier relationships, empowering companies to make informed decisions that yield both environmental benefits and economic value. By shedding light on these evolving dynamics within energy-intensive industries, our study identifies two main determinants that can effectively drive sustainable strategies.

Through this approach, there emerges a duality of benefits for companies investing in circularity and relationship management. Depending on their positioning - illustrated in Figure 1 - companies can identify suitable strategies (Figure 2) to develop a clear path aimed at realizing highly sustainable practices - such as industrial symbiosis - ultimately achieving high sustainability levels in alignment with the aforementioned triple bottom line.

6.3 Limitations and future research

While our research offers a distinctive perspective on sustainable commitment within energy-intensive companies, it is crucial to acknowledge the intrinsic limitations within our study design.

To address the main research question, we employed a combination of multiple case studies. However, like any research methodology, this approach has constraints, particularly concerning the number of participants involved. This limitation highlights an opportunity for scholars to enhance our findings by integrating a quantitative approach. Engaging a representative sample of companies across major energy-intensive sectors would ensure the generalizability of results and provide deeper insights into the four primary approaches identified: Explorers, Eco-Creators, Partner Dominating, and Symphonic Sustainability.

Furthermore, our study focused exclusively on the Italian context. Exploring sustainability strategies in different geographical settings could reveal both similarities and differences in the adoption of these identified approaches. Comparative analyses across various countries could illuminate contextual factors influencing sustainable practices and provide insights into effective strategies tailored to different industrial landscapes. Expanding research beyond its current scope presents an opportunity to enrich academic discourse and contribute to a more comprehensive understanding of sustainable business practices.

By incorporating quantitative methodologies and broadening the geographic scope of inquiry, future research endeavors can deliver actionable insights for companies aiming to achieve sustainable goals in diverse global contexts.

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