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DI PAVIA

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**Sustainable Manufacturing and
ESG Reporting Frameworks: EU
Taxonomy Implementation,
Strategy, and Long-Term Value
Creation at Pirelli & C. S.p.A.**

Supervisor:

Prof. Valentina Beretta

Author:

Beatrice Binda

Student ID:

549632

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ABSTRACT

In this research, the integration of the European Taxonomy (Regulation (EU) 2020/852) and of the new European reporting framework (CSRD/ESRS) within manufacturing enterprises is analyzed. In particular, a qualitative approach based on a single case centered on Pirelli & C. S.p.A. is used, seeking to fill gaps related to academic literature, which is mainly concentrated on the macro-sectoral level. In the research, an answer is provided to two research questions: the first concerning the implementation of the Taxonomy within the company (RQ1), the second refers to the managerial response aimed at overcoming regulatory and supply chain problems with the purpose of creating value in the long term (RQ2). From the investigation emerges the search for an adaptation methodology by the company. It had to identify its core business in Activity 3.6 of the Taxonomy, linking its substantial contribution to classes A/B of Rolling Resistance and Wet Grip of European Tyre Labelling. Aligned CapEx emerges as a leading indicator that drives the growth of sustainable Turnover; this path is visible in the 2021–2025 period. Faced with bureaucratization and supply chain obstacles (CSDDD, Scope 3, and EUDR), management did not delay in taking action. The responses provided were multiple, in terms of technology, strategy, and reliance on certifications in order to avoid greenwashing and integrate with sustainable finance. In conclusion, the comparison between literature and empirical results demonstrates that the Taxonomy did not shape Pirelli's industrial strategy, but only provided a foundation on which to structure the reporting method.

Keywords: EU Taxonomy, CSRD, ESRS, Sustainability Reporting, Manufacturing Sector, Cross-Functional Governance, Taxonomic KPIs (Turnover, CapEx, OpEx), Sustainable Finance, Case Study, Pirelli.

ABSTRACT

In questa ricerca viene analizzata l'integrazione della Tassonomia Europea (Regolamento UE 2020/852) e del nuovo quadro di rendicontazione europeo (CSRD/ESRS) all'interno delle imprese manifatturiere. In particolare, si utilizza un approccio qualitativo basato su un singolo caso incentrato su Pirelli & C. S.p.A., cercando di colmare lacune relative alla letteratura accademica, concentrata prevalentemente sul livello macrosettoriale. Nella ricerca viene fornita risposta a due quesiti di ricerca, il primo riguardante l'implementazione della Tassonomia all'interno dell'azienda (RQ1), il secondo fa riferimento alla risposta manageriale volta al superamento dei problemi normativi e di filiera con lo scopo di creare valore nel lungo periodo (RQ2). Dall'indagine emerge la ricerca di una metodologia di adattamento da parte dell'azienda. Essa ha dovuto identificare il proprio core business nell'Attività 3.6 della Tassonomia, collegando il proprio contributo sostanziale alle classi A/B di Rolling Resistance e Wet Grip dell'Etichettatura Europea. Il CapEx allineato emerge come indicatore guida che traina la crescita del Turnover sostenibile, questo percorso è visibile nel periodo 2021-2025. Davanti ad ostacoli di burocratizzazione e di filiera (CSDDD, Scope 3 e EUDR) il management non ha tardato ad agire. Le risposte fornite sono state multiple, in tema tecnologico, di strategia e di ricorso a certificazioni al fine di evitare il greenwashing ed integrarsi con la finanza sostenibile. In conclusione, il confronto tra letteratura e risultati empirici dimostra che la Tassonomia non ha plasmato la strategia industriale di Pirelli, ma ha soltanto fornito una base su cui strutturare il metodo di rendicontazione.

Parole chiave: Tassonomia UE, CSRD, ESRS, Rendicontazione di Sostenibilità, Settore Manifatturiero, Governance Interfunzionale, KPI Tassonomici (Turnover, CapEx, OpEx), Finanza Sostenibile, Studio di Caso, Pirelli.

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INTRODUCTION

The concept of sustainability has undergone an evolution over the years that deserves to be observed and understood. The term initially originated as an ethical, voluntary, and philanthropic dimension, linkable to Corporate Social Responsibility (CSR), subsequently evolving into a discipline that integrates the financial, governance, and control dimensions. Recent research has identified a problem in traditional production and consumption models; these have become unsuitable to address the climate and global urgencies reported in the IPCC reports.

With the introduction of the Green Deal in 2019 and the subsequent introduction of the European regulatory framework, the role of the enterprise was redefined. Sustainability therefore transforms into something quantifiable and subject to third-party financial verification (assurance).

However, contrasts emerge in the academic and managerial debate, specifically regarding theoretical models and their concrete applicability. Nowadays, capital- and material-intensive manufacturing enterprises face considerable operational obstacles (Corvellec et al., 2022; De Angelis, 2022; Shavkatov et al., 2024), contrary to what is described in the literature concerning governance and the Circular Economy, which speaks of the ecological transition as a pathway that generates value in a linear way (Bocken et al., 2016; Ellen MacArthur Foundation, n.d.). Companies must commit and bring innovation into their processes and practices to reduce the carbon footprint along the entire supply chain, from Scope 1 emissions up to Scope 2 and Scope 3 emissions.

The European Union has implemented an adoption plan within which regulations such as the CSRD, the ESRS, and Regulation (EU) 2020/852 (EU Taxonomy) are found. The latter introduces rules and classifications aimed at identifying which economic activities can be defined as

sustainable. To fall within this classification, large non-financial undertakings must report three key performance indicators (KPIs): Turnover, CapEx, and OpEx.

Despite the multiple existence of scientific literature regarding sustainability and European regulations (Alessi et al., 2024; Garcia-Torea et al., 2024; Hummel & Bauernhofer, 2024), the literature presents a significant gap (Alessi et al., 2024; Brabec & Macháč, 2026). For the most part, analyses exist at a macro-sectoral level with a shortage of studies at a micro-organizational level; it is therefore little explored how large manufacturing enterprises, located in energy- and material-intensive sectors (hard-to-abate), perceive the EU Taxonomy.

To fill this gap, the Tyre & Rubber sector can be considered suitable for this purpose. It is characterized by high material usage (natural and synthetic elastomers, silica, and other chemicals), greenhouse gas emissions, and a series of impacts along the life cycle of its products (among these are deforestation, tyre wear particle emissions, and tyre end-of-life management).

From these premises arises the subject of this research, namely the analysis of the Pirelli & C. S.p.A. Group, a leader in the Consumer High Value sector. This case helps answer two specific research questions:

RQ1 *How has the European Taxonomy been implemented by Pirelli (methodology, KPIs, relationship between functions, information systems)?*

RQ2 *What organisational, informational, and compliance challenges arise from the implementation of the EU Taxonomy, and how does management address them to create long-term value?*

CHAPTER 1

1.1 Definition of sustainability and historical evolution

In recent years, themes related to sustainability have assumed an increasingly central role in the economic and business context.

To best understand the role of sustainability, one can begin with the definition of this concept and its evolutionary timeline.

This concept developed through a progressive path, focusing initially only on environmental aspects and then moving to something broader that includes socio-economic dimensions.

The word “sustainability” comes from *sustinere*, it means to defend, to sustain and to take care. (Dossi, 2024)

This term refers to the capability of using resources and undertake activities in a way that can be maintained during the time and that won't harm the environment or the society. It is a responsible management of resources in order to grant the use to future generations. This word began to be used between the '60 and '70, thanks to environmentalist movements that began to make themselves heard in 1968. (Lorenzo, 2024)

In 1973 the UN intervened on this topic. UNEP was built, United Nations Environment Programme, this entity operates against climate change and wants to protect environment and natural resources. The UNEP was founded because of oil crisis of 1973, this was a first link between environmental crisis and socio-economic crises. (Lorenzo, 2024)

Parallel to these developments, in the 50s the relationship between business and society was put in discussion by economic-business doctrine through the concept of CSR (corporate social responsibility). In 1953, Howard Bowen speaks about “social responsibilities of the businessman”, he sustains that managers should take in consideration the consequences

of their own decisions on workers, society and environment, they must not consider only the mere profit.

But an opposite vision establishes itself in the 70s, that of Milton Friedman. He in his theory sustains that the only social duty to which the business is subjected is that of creating and maximizing value for shareholders. Binding itself to the logic of shareholder primacy. (Mio, n.d.)

A first breakthrough is obtained in the 80s. It can be said that the classic/basic definition of sustainability comes from sustainable development. This concept was introduced in 1987 in Stockholm by “Our Common Future” report also known as Brundtland report of World Commission on Environment and Development (WCED). This report defines sustainable development as: *“A development is sustainable when it satisfies the needs of the present without compromising the ability of future generations to satisfy their own needs”*. Also here, it is highlighted the connection between social, economic and environmental dimensions. It indicates the transition from a simple protection of the environment, to a broader vision that includes the protection and safeguard of these 3 dimensions. Numerous authors sustain that the Brundtland’s definition will constitute a point of reference for all the future reworkings of the concept of sustainability and sustainable development, it will be the starting point of many CSR strategies and ESG criteria. (Mio, n.d.)

In the nineties, there is a shift from the general responsibility of the business to a measurement of its non-financial performance. A special contribution is the one of John Elkington, he proposed the Triple Bottom Line model (TBL). (Tami et al., n.d.)

He introduced the 3Ps (People, Planet and Profit). This model is based on the fact that instead of measuring the enterprise success only in terms of profit (economic bottom line), it reports the impact on people (social

dimension) and on the planet and environment (environmental dimension). (Buallay, 2022)



Source: https://www.researchgate.net/figure/The-interconnection-of-the-elements-of-the-Triple-Bottom-Line-concept_fig1_329185478

This model represents in managerial terms what is written in the Brundtland report. It also connects the philanthropic CSR with the possibility to now measure sustainability as a measurable performance. As a consequence to this, the first reporting standard was born, an example can be the first GRI guidelines. (Moneva et al., 2006)

Sustainability, in this first phase, began to be perceived not only as a moral obligation, but as a factor that can be used by the enterprises to compete against each other in the field of innovation of products and processes without leaving aside the respect for social and environmental dimensions. (Elkington, 1997) (Porter & Kramer, 2006)

Later on, between the nineties and the noughties the Dow Jones Sustainability Index was launched on the market, it was the first stock market index that ranked / selected companies basing on social and

environmental criteria other than the economic ones. (*The Benchmark That Changed the World*, 2019)

In 2000 the Global compact of united nations and the Millennium Development Goals, that precede the current Sustainable Development Goals (SDGs) were born. (*Millennium Development Goals (MDGs)*, n.d.)

Thanks to this two creations, governments and enterprises were oriented to integrate sustainable practices in their own strategies. In this way, the idea began to emerge according to which, the orientation of capitals towards sustainable activities had to happen through a common language for everyone, including financial markets. Thanks to this intuition, the ESG criteria were created (Environmental, Social, Governance). (*Overview of Sustainable Finance - Finance - European Commission*, n.d.)

Various sources give credit for the birth of the acronym to the “Who Cares Wins” report of 2004, promoted by Global Compact and a group of big financial institutions. In this report it is demonstrated how the various environmental, social and governance factors contribute to the long run risk evaluation and performance. It can be said that this document is an invitation for analysts and investors to include these factors in their analysis models. (The Global Compact, n.d.)

The Freshfields Report of UNEP Finance Initiative also states that it is a fiduciary duty of investors to consider ESG factors, leading to a more “responsible” finance and to the creation of the Principles for Responsible Investment (PRI). (UNEPFI, n.d.) (Russell Investment, n.d.)

From this moment on, the acronym ESG became a reference for indexes, rating and investment policies. Sustainability is now shown not only on the balance sheets but is now also measured and has a price on the markets. (International Organization of Securities Commissions, n.d.)

In 2015 new elements were introduced. Among these, the adoption of the 2030 Agenda and the introduction of the 17 Sustainable Development Goals (SDGs) are encountered, they define objectives that relate to climate, poverty, inequalities, consumption of resources and governance of institutions. (*THE 17 GOALS | Sustainable Development*, n.d.) (I. L. O., n.d.)

At the European level, the Commission presents in 2019 the European Green Deal. It's a strategy for the growth of the EU and aims to achieve climate neutrality by 2050 and a reduction of at least 55% of emissions by 2030. (*The European Green Deal - European Commission*, n.d.) (*Parlementaire Monitor - Parlementaire Monitor*, n.d.)

In order to accomplish these objectives, the EU launches an Action Plan for sustainable finance. This includes the SFDR, the CSRD and above all the Regulation (EU) 2020/852 on the Taxonomy of sustainable activities. This last one defines which economic activities are aligned with EU environmental objectives and which are not aligned. (*Overview of Sustainable Finance - Finance - European Commission*, n.d.) (Burcea, 2025)

It can be said that there was an evident shift from the concept of sustainability as an ethical principle, passing through the definition of CSR, the Triple Bottom Line model, the creation of the ESG factors used by both markets and investors until reaching regulations like EU Taxonomy and CSRD. These norms were able to transform sustainability into duties of measurement, reporting and integration of decisional processes of the company. (Mangiuc & Kagitci, 2025)

Through this historical timeline it's possible to understand why today for many enterprises (especially the manufacturing ones), sustainability means KPIs, costs and revenues more and more aligned to a regulatory

framework, not only based on values or communication. (Ecobiomanager, n.d.)

1.2 ESG dimensions

Nowadays enterprises report, measure and evaluate their own sustainability performance thanks to one of the main interpretative schemes: the ESG dimensions. ESG is an international acronym and indicates Environmental, Social and Governance. These are three crucial factors to understand the commitment of a company in sustainability and its ethicality. These non-financial metrics allow investors, clients, consumers or regulators to understand the long-term potential of a company and consequently take decisions. They are therefore essential for the company to understand where to improve and how to innovate its own processes in order to have a positive impact on the environment and on society. Especially if it relates to enterprises that operate in the manufacturing sector. (GreenScope, n.d.) (Karashima, 2024)

By now all sectors are aligning themselves to ESG criteria and among the most renowned there are: finance and the industrial sector, but also the technological sector, retail and health. The objective of ESG criteria is therefore to try to encourage companies to undertake sustainable and responsible practices. The evaluation based on ESG metrics involves various stakeholders, including: the company and its employees, financial entities and investors, but also actors belonging to society (consumers, NGOs and many others). (GreenScope, n.d.)

The letter “E”, the first of the acronym, stands for Environmental. This first dimension refers to the impacts on the environment and on the planet, with a look at carbon emissions, use of resources, waste management and pollution. The objective of this dimension is to direct companies towards a more sustainable use of resources, reduction of emissions and improvement of efficiency. (The Corporate Governance Institute, n.d.)

The letter “S” refers to Social. It particularly involves stakeholders that gravitate around a company (employees, clients, suppliers and communities). This dimension commits to ensure better human rights, labor standards, diversity and social involvement. All through an ethical management of people and suppliers, guaranteeing fair employment, same opportunities, the right balance between work and private life and the respect of the rights of people. (The Corporate Governance Institute, n.d.)

The letter “G” stands for Governance, it regards the measurement of the management and administration of the company. It refers to the levels of remuneration and the differences between these (between the highest salary and the lowest one), rights of shareholders and representation of minorities. But also relationship with suppliers, customer satisfaction and independence of the BoD. (The Corporate Governance Institute, n.d.)

In order to provide a clear and transparent analysis of the sustainability and ethicality of the corporate performance, the ESG evaluation must be based on these three factors. The results will be finally used to take decisions related to future investments or as an invitation to the company to evolve its own strategy. (GreenScope, n.d.)

The ESG criteria constitute the foundations of many norms, references and evaluations used by different companies. The CSRD, or the Global Reporting Initiative (GRI), or the International Sustainability Standards Board (ISSB) and the Sustainability Accounting Standards Board (SASB) are all based on the three ESG dimensions. (GreenScope, n.d.)

The Global Reporting Initiative (GRI) is the most used framework. It helps with the creation of sustainability reports and continues to grow in importance. Importance is given by the increase of the request from stakeholders, legislative need and also the growing competitiveness in showing the best compliance to ESG criteria. The Sustainability

Accounting Standards Board (SASB) deals with creating specific standards for each sector with a look at the critical points for financial performance. (The Corporate Governance Institute, n.d.)

In addition to regulations, frameworks and standards, ESG ratings and indices have also been developed (Sustainalytics, Morgan Stanley Capital International MSCI, Dow Jones Sustainability Index DJSI). From these latter it is possible to obtain total scores that refer to the performance of the company. They are based on the three ESG pillars. Investment decisions, but also decision on which supplier to rely on depends on these scores as they are comparable among each other (if the method on which the evaluation is based is the same). Moreover, to ensure the complete coherence of the reporting, companies are subjected to audit. (GreenScope, n.d.)

ESG reporting is the method through which performances and environmental impacts of a company are communicated. With the arrival of national and international regulations, including the CSRD or SFDR in the European Union, this type of reporting is by now essential for stakeholders and companies. The reporting helps investors and other actors to evaluate the risks related to the three Environmental, Social and Governance dimensions. It is an essential tool to attract financing and improve the reputation of companies. (GreenScope, n.d.)

For the creation of these reports, the tools needed to measure ESG performances are: ESG Software SaaS or OnPremise. All available on the market. The softwares collect data, organize them, check if they are coherent with the various norms and finally transform them into reports. Those will be compared by the management to those of similar enterprises to see if the company is doing well and where it presents criticalities. (GreenScope, n.d.)

ESG reporting presents both obstacles, but also benefits for companies. Data collection does not always happen in a simple way, there can be difficulties and complications. To this is added the risk of greenwashing and the barriers to the integration of ESG in business strategies. On the other side, however, ESG reporting, as said before, leads to a better reputation, risk reduction, attraction of new talents that bring even more innovation to the company. (The Corporate Governance Institute, n.d.)

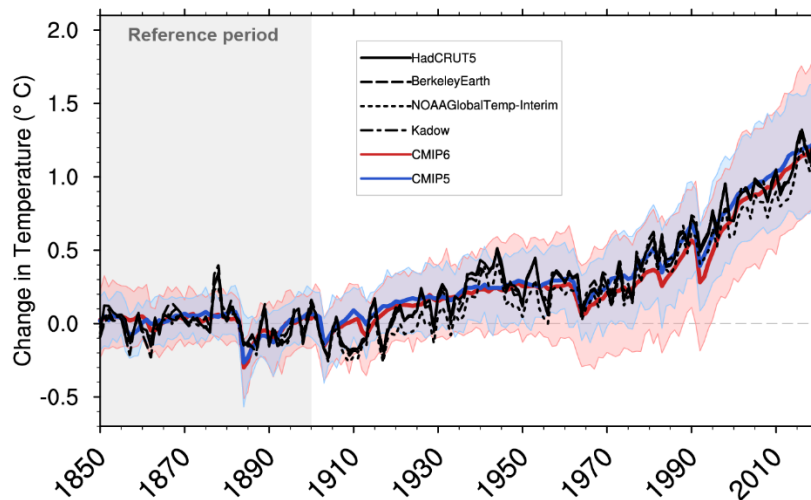
1.2.1 The global challenges

The manufacturing industry has made great progress in trying to integrate sustainable practices into its own processes. However, there still exist many challenges and difficulties to face.

To fully understand the global challenges, one must begin starting from the concept of causal chain of climate change, also called “climate-energy-economy nexus”. In practice, this is an infinite cycle. Economic activities generate emissions, which then increase the concentration of greenhouse gases in the atmosphere, leading to radiative forcing which is the cause of global climate change. The cycle repeats, because global change impacts on the local one and finally on the economy.

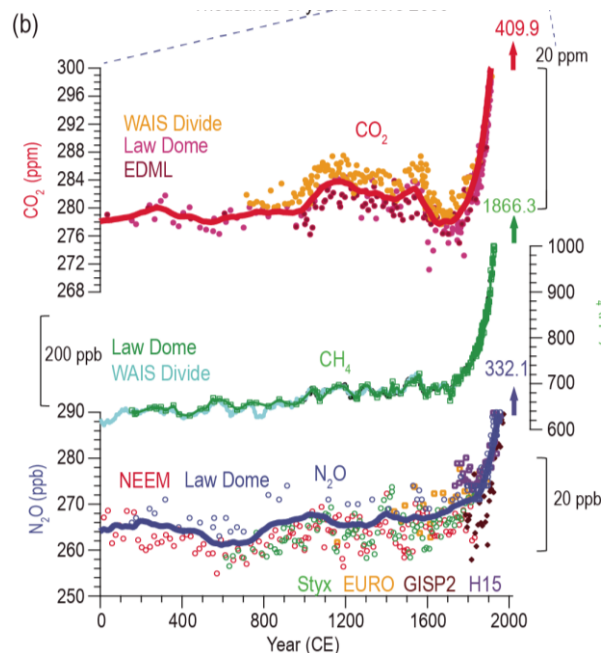
Climate change, according to scientific bases, is given by the increase of the energy balance of the earth system due to anthropogenic greenhouse gas emissions and other human activities. This statement is supported by various scientific proofs, multiple measurements and solid theoretical interpretations. (Intergovernmental Panel On Climate Change (Ipcc), 2023)

Through the measurements it can be confirmed that the situation has worsened over the course of the last 150 years, the global average temperatures are in constant increase. The rate and the level of warming are among the highest in recent human history. (Intergovernmental Panel On Climate Change (Ipcc), n.d.)



Source: <https://www.ipcc.ch/report/ar6/wg1/figures/chapter-3/figure-3-4>

Additionally, the concentration of well-mixed greenhouse gases (such as CO₂) in the atmosphere has increased over the last century. Currently, the concentration is measured through atmospheric samples, while in the past ice cores were used, which trapped air bubbles, preserving them in their original chemical composition.

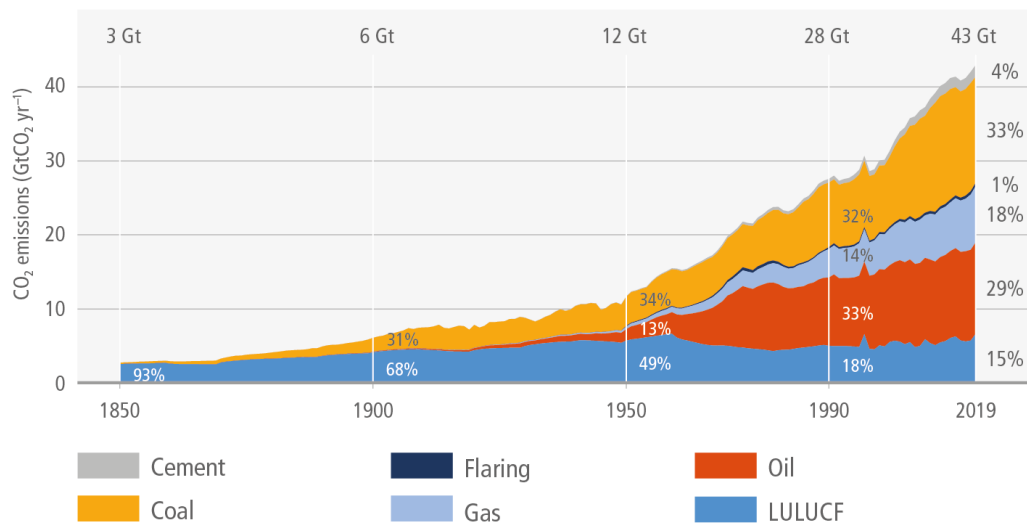


Source: <https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-2/>

Another measurement regards the anthropogenic emissions of well-mixed greenhouse gases that have also been steadily increasing in the past

century, for CO₂ mainly due to burning fossil fuels. Bottom-up estimates (aggregating national inventories) combined with knowledge over the carbon content of fossil fuels provide precise estimates of past greenhouse gas emissions. Land use change is more uncertain but also a smaller contributor of total CO₂ emissions. (Osibodu et al., 2024)

(a) Long term trend of anthropogenic CO₂ emissions sources

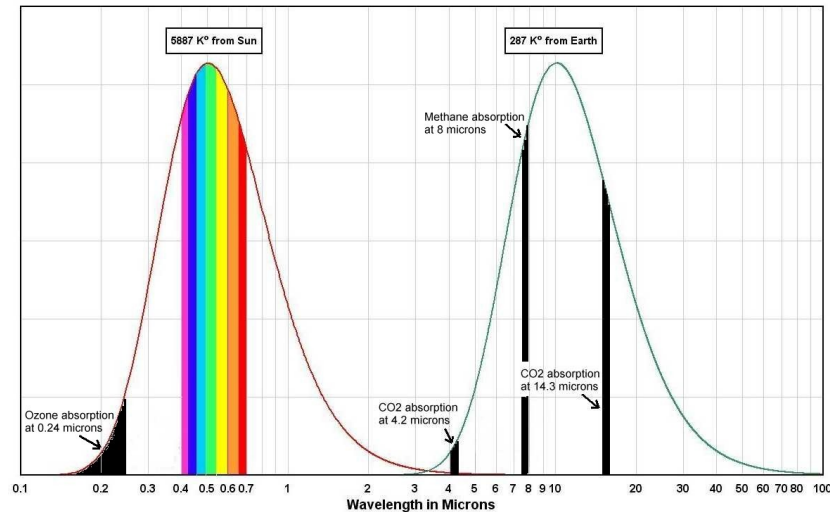


Source:

https://www.researchgate.net/publication/386383272_Phase_change_material_integration_in_concrete_for_thermal_energy_storage_techniques_and_applications_in_sustainable_building/figures?lo=1

The scientific theory of greenhouse gases provides a causal interpretation for the correlation between these three measurements.

Greenhouse gases absorb the infrared radiation emitted by the earth, but don't interact with incoming solar radiation. Therefore, they increase the earth's energy balance and thus surface temperature. Other gases or particles absorb (ozone) or reflect (aerosols) incoming solar radiation, that being emitted at a much higher temperature travels at different wavelengths. (Mcsweeney, n.d.)



Source: https://onlinelibrary.wiley.com/doi/epdf/10.1002/ciuz.201900061?saml_referrer

In this broad context, the manufacturing sector must be capable of aligning itself to ESG parameters. In the first dimension (Environmental) among the most important challenges, Carbon Reduction and Waste Management can be cited.

For the first one, manufacturers commit to align themselves to international climate targets, especially those outlined by the Paris Agreement. The agreement foresees the achievement of net-zero emissions by 2050. In trying to satisfy these objectives companies must face various obstacles. The Scope 3 Emissions are among these, they consist in indirect emissions generated along the supply chain (raw materials, transport and use of products). The difficulties in alignment to the requirements of Scope 3 Emissions, is reported by approximately 70% of manufacturers. These complications derive from the fact that not all producers have complete visibility of the various processes of their own supply chains. So it results difficult for them to reduce the emissions of their own suppliers and logistic partners. (Karashima, 2024)

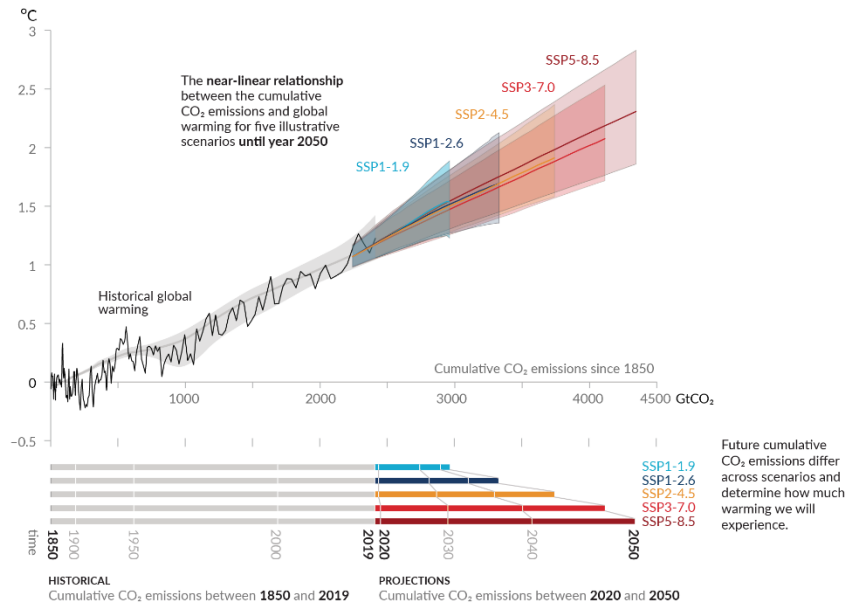
Connecting to what has just been said, CO₂ is a long-lived greenhouse gas, also called stock pollutant, it persists in the atmosphere for centuries or even millennia. Its effect depends on cumulative emissions over time.

Consequently decarbonization in the manufacturing sector cannot be something that depends on a short-period adjustment. On the contrary, it derives from a long-period structural transformation in order to reduce the emissions accumulated in the system. (Harrison, 2018)

Moreover, a quasi-linear relationship can be highlighted between the cumulative emissions of CO₂ and the global temperature increase, even if uncertain. This relationship is defined Transient Climate Response to Cumulative Emissions (TCRE). Therefore, every ton of CO₂ emitted by manufacturing industries contributes to the worsening of climate risk. (Rogelj, 2021)

Every tonne of CO₂ emissions adds to global warming

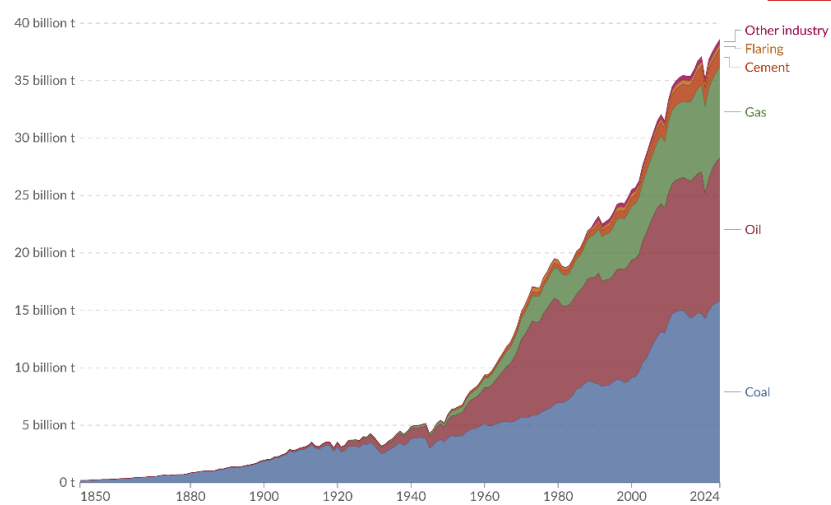
Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO₂ emissions (GtCO₂)



Source: <https://www.realclimate.org/index.php/archives/2021/08/a-deep-dive-into-the-ipccs-updated-carbon-budget-numbers/>

CO₂ is largely emitted from burning fossil fuels to produce energy, plus a minority from industrial processes (e.g. cement and chemical production), and land use change. (Our World in Data, n.d.-a)

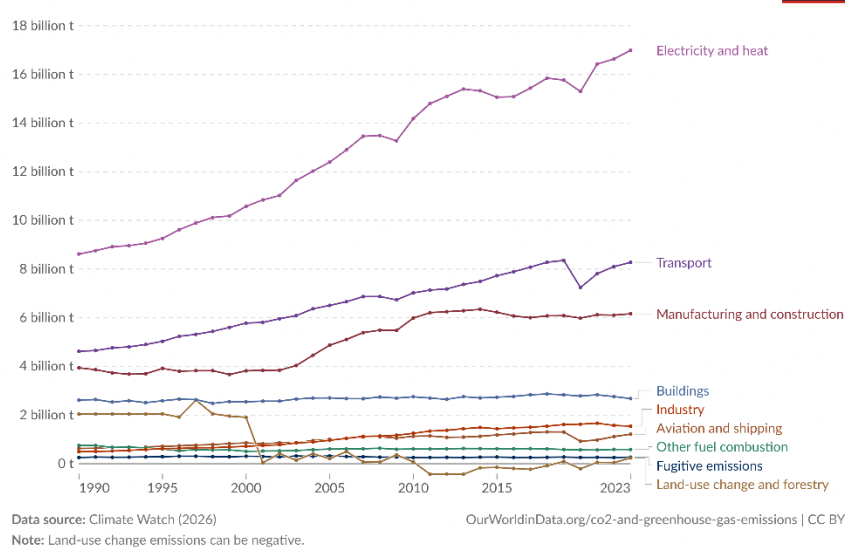
CO₂ emissions by fuel or industry type, World



Source: <https://ourworldindata.org/grapher/co2-by-source>

Electricity and heat are the major contributors of CO₂ emissions, followed by transport and industry sectors. For most of the sectors, CO₂ is emitted via fossil fuel energy production for direct (heat) or indirect (electricity) uses. (Our World in Data, n.d.-a)

CO₂ emissions by sector, World



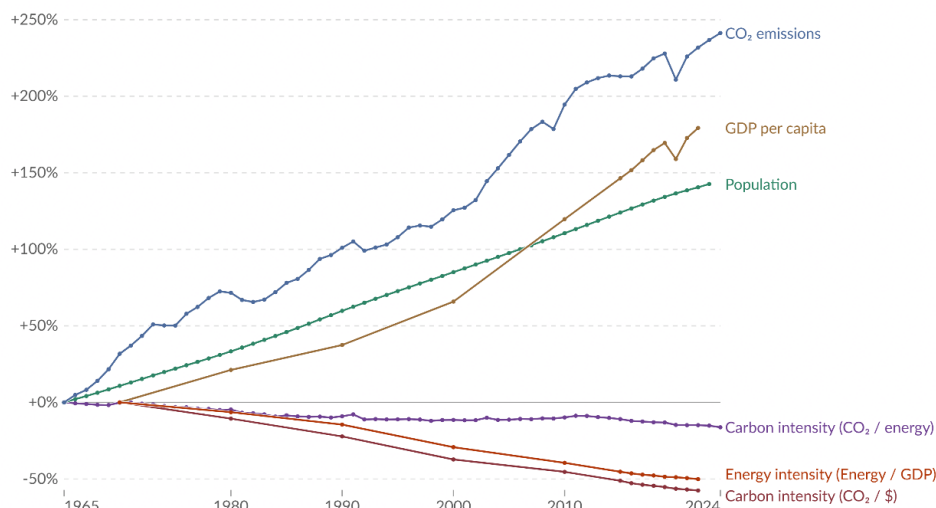
Source: <https://ourworldindata.org/grapher/co-emissions-by-sector>

Another driver of CO₂ emissions is the growth of economic activity. It can be said that it is one of the major contributors. We have become much more efficient in using energy to produce output (Energy / GDP). Partly

because of increasing material efficiency in processes, partly because more income comes from less energy intensive sources (services). Carbon intensity slightly decreased, indicating a partial shift from more polluting (coal) to less polluting forms of energy (gas, renewables). The graph below highlights the Kaya Identity, namely the model used to understand which are the factors that influence the production of CO₂ (GDP, Population, Energy consumption and Carbon Intensity). (Our World in Data, n.d.-b)

Kaya identity: drivers of CO₂ emissions, World

Percentage change in the four parameters of the Kaya Identity, which determine total CO₂ emissions. Emissions from fossil fuels and industry¹ are included. Land-use change emissions² are not included.



Data source: Global Carbon Budget (2025) and other sources
OurWorldinData.org/co2-and-greenhouse-gas-emissions | CC BY
Note: GDP per capita is measured in 2011 international-\$³ (PPP). This adjusts for inflation and cross-country price differences.

Source: <https://ourworldindata.org/grapher/kaya-identity-co2>

Regarding the Waste management challenge, the most relevant one is electronic waste (e-waste). In 2022, a record of 62 million tons of e-waste was registered. The manufacturing sector, especially that of consumer goods and electronics, is one of the main producers of this type of waste. (Baldé C. P., Ruediger Kuehr, Tales Yamamoto, Rosie McDonald, et al., 2024)

E-waste imposes many regulatory and logistical constraints that require attention in the handling and recycling of these materials, often rich in hazardous substances. Consequently, the increase in electronic waste

complicates the commitment to sustainable recycling. The environmental pressures generated are not limited to the mere production phase, but extend to the entire product life cycle. (Baldé C. P., Ruediger Kuehr, Tales Yamamoto, Rosie McDonald, et al., 2024) (Karashima, 2024)

Waste management, therefore, is one of the points on which the sector must intervene to reduce the various impacts.

From the perspective of the Social dimension, supply chain transparency is one of the most significant social issues. Often, as previously cited, manufacturing companies do not have complete visibility on their supply chains. This leads to difficulties in complying with labour standards, environmental regulations, and ethical sourcing. (Karashima, 2024)

It is therefore important for companies to be transparent not only on the environmental side (emissions, impacts), but also on the ethical and social side to identify possible vulnerabilities of their production chain.

Another issue of the Social dimension is health and safety standards. Working in unsafe and unhealthy environments increases the risk of accidents and injuries at work, especially for manufacturing companies that are equipped with heavy machinery, potentially harmful chemical products, and dangerous working conditions. For this sector, the International Labour Organization (ILO) reported about 2.8 million work injuries in 2022. (International Labour Organization, 2024)

Continuous investments in worker training, courses, safety measures, and technologies to prevent accidents are necessary to ensure health and safety for all company actors. (Karashima, 2024)

In the Governance dimension, among the various challenges there is regulatory complexity. In Europe, companies must comply with the Corporate Sustainability Reporting Directive (CSRD), which requires a detailed report on ESG information. In the US, instead, the Securities and Exchange Commission (SEC) has introduced rules on climate reporting

for public companies. The difficulty for multinational companies lies precisely in the ability to adapt to various regulatory frameworks that often clash with each other. This requires a greater expenditure of resources by companies. (European Commission, n.d.-a) (Security and Exchange Commission, n.d.) (Deloitte, n.d.)

Another difficulty concerns the tracking of various ESG metrics, the introduction of various reporting systems, and the request to adapt to continuous regulatory changes. (Karashima, 2024)

Finally, Data Quality is a key challenge. For reporting, precision and completeness in data collection are required, because inaccurate or incomplete data cause the loss of credibility and reputation by the company and consequent penalties. Therefore, it is necessary that the company invests in systems and technologies that ensure accurate data collection. Also, in the training of its employees in order to know how to best exploit these systems. (KPMG, n.d.) (Jonsdottir et al., 2022)

1.3 Paradigm and opportunities of circular economy and sustainable manufacturing

From the beginning of the production process until the end of the product's life, business models should be resilient, transparent and sustainable. The circular economy is an important point in the ESG strategies of a company. This replaces the linear model of the product's life (produce, use and discard), it is based on regeneration which aims to reduce waste and maximize efficiency. (ASUENE, 2025)

According to Ellen MacArthur Foundation: “A Circular Economy is an economy based on the principle of keeping products and materials in use, maximizing the value of resources, and thus regenerating natural systems”. (Ellen MacArthur Foundation, n.d.)

The paradigm of circular economy aims therefore to overcome the classic linear model “take-make-dispose”. Enterprises extract raw materials,

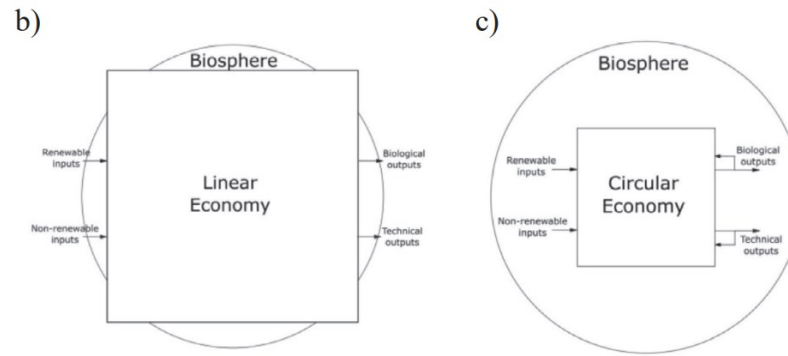
transform them into products that at the end of their life cycle are thrown into landfills or incinerators. This scheme has always been used. In fact, it has favored economic growth, but it has at the same time created an enormous consumption of non-renewable resources and a very important accumulation of waste and emissions. (Brändström & Saidani, 2022) (Kirchherr et al., 2017)

The Linear Economy



Source: <https://newvibe.altervista.org/linear-economy-vs-circular-economy/>

On the contrary, the circular model has a completely different conception of the product's end of life. This concept is based on the reduction, reuse and recycling of materials along the entire process of production, distribution and consumption. Reducing means trying to use as few resources and energies as possible. Reusing connects to the fact of extending the life of one's own products or components through repair, remanufacturing or business models based on service. Finally, recycling is based on the reintroduction of materials contained in a product, inside production processes. (Brändström & Saidani, 2022; Kirchherr et al., 2017)



Source: https://ars.els-cdn.com/content/image/1-s2.0-S0959652618340009-egi10RV0XLSR5J_lrg.jpg

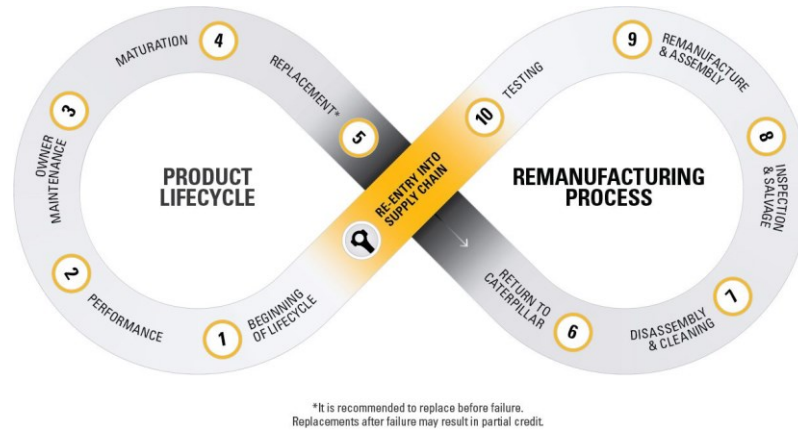
This systemic change from linear to circular regards multiple levels: micro (product, enterprise, consumer), meso (districts and eco-industrial parks) and macro (industrial policies, norms and infrastructures). The objective is therefore: to reduce the demand and the extraction of new resources and the production of waste, prioritizing the reuse of existing materials. In this way companies can align themselves with the goals of sustainable development. (Kirchherr et al., 2017)



Source: https://www.researchgate.net/figure/The-system-level-approach-to-circular-economy-describes-the-actors-on-macro-meso-and_fig1_332222148

Large manufacturing companies are investing in closed-loop systems, an example can be Caterpillar. This company has developed the Cat Reman® program: when possible they try to reuse their own resources, offering to clients rapid and reliable assistance at reduced times and costs. The

products enter Caterpillar towards the end of their life cycle and come out like new, an excellent solution to reduce waste. Another program always implemented by the company is the Cat Rebuild Program, which has the advantage of bringing to machineries or components the most recent engineering and technological innovations based on the client's budget. (Caterpillar, n.d.) (Cat, n.d.)



Source: https://www.cat.com/en_US/blog/the-circular-economy-cat-reman-and-sustainability.html

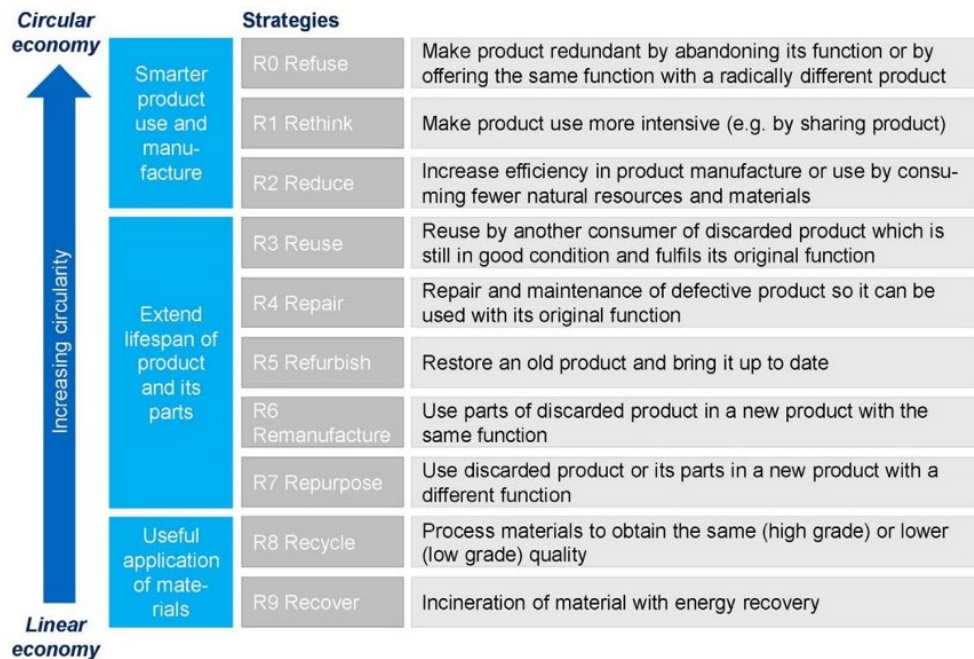
Other circular economy initiatives have also been implemented by Philips (100% of their products are built in such a way that they can be recycled), Unilever (Refillable packaging in more than 30 markets), Siemens (remanufacturing of turbines and engines which consequently leads to a reduction in the use of raw materials of approximately 60%). As said previously, decarbonization is one of the most pressing objectives for the manufacturing sector. Companies try to reduce their Scope 1, 2 and 3 emissions because of regulatory pressures and investor demand. Among the various initiatives to reduce emissions: the electrification of industrial processes, introduction of green hydrogen in high-temperature processes, use of renewable energy produced on site. (ASUENE, 2025)

Many definitions of circular economy stop simply at the 3Rs (reduce, reuse, recycle), but this is reductive. The CE must include a true change

within the economic system, it must not only aim at a better management of waste. For this, returning to what was said previously, the various micro, meso and macro levels are relevant. The interaction of these levels allows to pass from a single and simple technical intervention, to a transformation of the supply chain and of the context in which it operates. It is necessary therefore to coordinate the change of design, production, distribution, consumption and end of life of the product. In this sense, the Circular Economy must be interpreted as a true system paradigm and not a set of recycling techniques.

The part of literature analyzed by Kirchherr et al. describes the CE through R-frameworks. Often the scheme of the 3Rs (reduce, reuse, recycle) was used, which then was extended to the 4Rs (3Rs + Recover). Finally, in more recent works, the 9R Framework was introduced, which is the most complete. The scheme of the 9Rs puts in order the strategies according to a real hierarchy. At the top, are presented those strategies that reduce upstream the use of resources (Refuse R0, Rethink R1, Reduce R2). In the center there are those that help to prolong the life of components and products (Reuse R3, Repair R4, Refurbish R5, Remanufacture R6, Repurpose R7). At the bottom, finally, are located the strategies that intervene on materials at the end of life (Recycle R8 and Recover R9). The logic behind this framework is that one should prioritize strategies from

R0 to R7, which bring more value. Strategies R8 and R9, instead, should be considered exclusively as a final solution. (Kirchherr et al., 2017)



Source:

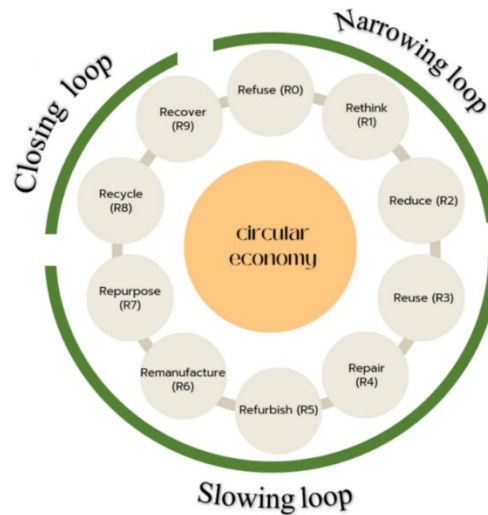
https://www.researchgate.net/publication/321432839_Conceptualizing_the_circular_economy_An_analysis_of_114_definitions/figures

In the manufacturing context, CE offers many opportunities that deal with the entire life cycle of the product. Eco-design is an initiative that includes from the beginning to the end the reduction of the use of materials, ease of disassembly, selection of durable and reusable components, repair and recycling. This approach, in fact, respects the idea presented in the literature, namely that CE strategies are not limited to the sole management of waste.

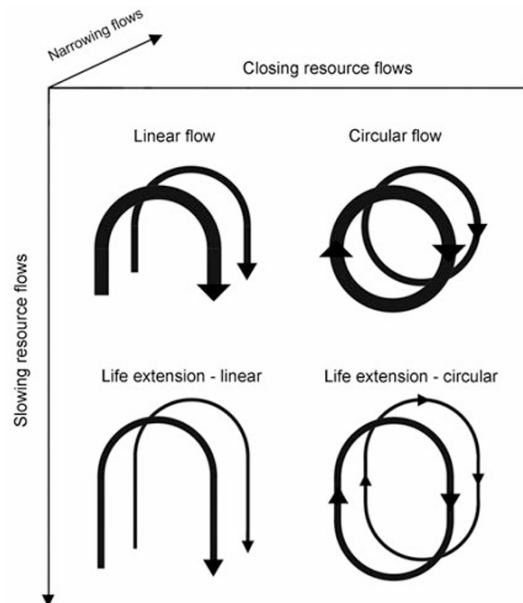
Among the opportunities there are the “closing loops” strategies. This typology of strategies is based on the high-quality recovery of materials at the end of life, which will be then reintroduced into the production cycle. In this way, the demand for raw materials and materials can be reduced, always maintaining the same function of the products. This implies for companies a minor dependence on raw materials and greater resilience to the volatility of their prices. (Bocken et al., 2016) (Brändström & Saidani, 2022; Kirchherr et al., 2017)

Another family of strategies is “slowing loops”. Here the useful life of products is extended through increase of quality, maintenance and repair, refurbishing and remanufacturing. In the case in which a product were designed with durable materials and maintained correctly, its useful life would increase. The enterprise will benefit from a minor consumption of materials, reduced production of waste and a reduction of environmental impacts. Remanufacturing and refurbishing become new business areas of the manufacturing sector.

Finally, “narrowing loops” strategies aim to reduce the quantity of resources used to provide a given function. One intervenes both on the design of the products and on the way in which these are used. This happens thanks to a minor use of materials per unit of product or the adoption of sharing models. For example, companies can create a product that is lighter and more efficient simply by using less matter and reducing the energy necessary to use it (if it weighs less, it can consume fewer kWh). If the company has products that are scarcely bought, it can simply adopt sharing or rental models. It will produce fewer products, but these will be used more, reducing the consumption of materials. This opens the way to servitization, the value will no longer be linked to the number of pieces sold, but to the efficiency of the function. (Bocken et al., 2016)



Source: <https://link.springer.com/article/10.1007/s00170-025-16109-2>



Source: https://www.researchgate.net/publication/309699661_Product_design_and_business_model_strategies_for_a_circular_economy

From the literature emerges that the three combined strategies are more efficient compared to when they are considered individually. Through this combined scenario one manages to reduce the environmental impact compared to a scenario of Linear Economy. For the manufacturing sector the opportunities are many and it is necessary to learn to exploit them. (Bocken et al., 2016)

It can be said that these 3 strategies are complementary to the 9R framework, given that Closing Loops refer to Recycle and Recover, Slowing Loops to Reuse, Repair, Refurbish, Remanufacture, Repurpose and Narrowing Loops to Refuse, Rethink, Reduce. In the manufacturing context, CE presents opportunities for transformation of products and processes. Taking into consideration the case of a durable product, the strategies of Closing, Slowing and Narrowing Loops demonstrate several benefits compared to the linear model. Quality recycling, the extension of useful life and the reduction of the use of materials lead to decreasing the demand for raw materials. In the same way, they also allow to reduce the waste generated and the environmental impact indicators. This demonstrates that CE is not based on a single technology, but on a set of levers that act along the entire life cycle of a product. (Taisch & Acerbi, n.d.)

A first area of opportunity is represented by circular design or eco-design. Acerbi and Taisch define it as an essential passage in which to limit the use of resources, facilitate disassembly, implement reuse and remanufacturing. Designing according to circular principles means integrating aspects such as modularity, disassembly, durability and upgradeability. This allows to make the strategies for the recovery of materials and extension of useful life, sustainable also from the economic side. Always from this side, it will be possible to create new business opportunities linked to the second life of products and components. From the social point of view, it is possible to satisfy the requests of clients to create durable and easy-to-maintain products. From the environmental side, as already said, the consumption of virgin materials and the production of waste is reduced. (Beducci et al., 2024)

The opportunity given by disassembly and remanufacturing is strictly connected to the previous one. In their work Acerbi and Taisch

demonstrate that the disassembly of products into subcomponents is fundamental to benefit from strategies such as remanufacturing. This strategy allows to create value from products that for the user have lost their utility. Remanufacturing allows to bring back to new used products, reducing in this way the initial phases of production, energy and processing. Manufacturing in this case can be interpreted as management of return flows (reverse logistics) and regeneration, which will lead to economic (reduction of costs), environmental and occupational benefits (new roles of inspection, disassembly and regeneration). (Beducci et al., 2024; Taisch & Acerbi, n.d.)

Another field regards cleaner production and material efficiency, which correspond to narrowing loops, oriented to the reduction of resources per unit of output. As far as cleaner production is concerned, the aim is to optimize processes, reduce scraps and consumption. Material efficiency instead points to a lower use of materials both during design and during the use of products, always maintaining the same function. These strategies represent for manufacturing companies a double opportunity: an improvement of environmental performances (minor emissions and minor pressure on resources) and a competitive advantage given by the containment of costs and resilience to the volatility of prices of raw materials. (Choi et al., n.d.) (Taisch & Acerbi, n.d.)

Servitization through product-service systems is another great opportunity. PSS, according to Acerbi and Taisch, allow to sell a service through the use of the product. This strategy exploits tangible elements (the physical good) and intangible ones (services of maintenance, upgrade, substitution) to satisfy the client's requests. Also this strategy remains coherent to narrowing loops, satisfying the same needs of clients with a lower number of products. This represents an incentive for manufacturing

companies to design reliable, repairable and upgradeable products. (Bocken et al., n.d.)

Finally CE offers opportunities linked to closed-loop supply chain and industrial symbiosis. The closed-loop supply chain, also called Reverse Logistics, aims to establish an inverted flow of resources along the entire supply chain. These return flows involve used products, components and materials that would be otherwise discarded without this strategy. In this way, it is possible to distribute more value among the actors of the supply chain. (Lapko et al., 2019)

Industrial symbiosis and eco-industrial parks make reference to the physical exchange between companies of different sectors, of resources such as materials, energy and by-products. This strategy allows therefore companies to use the process scraps of another company, as input for their own processes. The advantages that closed-loop supply chain and industrial symbiosis bring are various, from the environmental side there will be a minor production of waste and squandering, from the economic side an obvious reduction of disposal costs and new revenues from by-products. Finally, from the social side, new skills and jobs can be created to manage these circular flows. (Domenech et al., 2019)

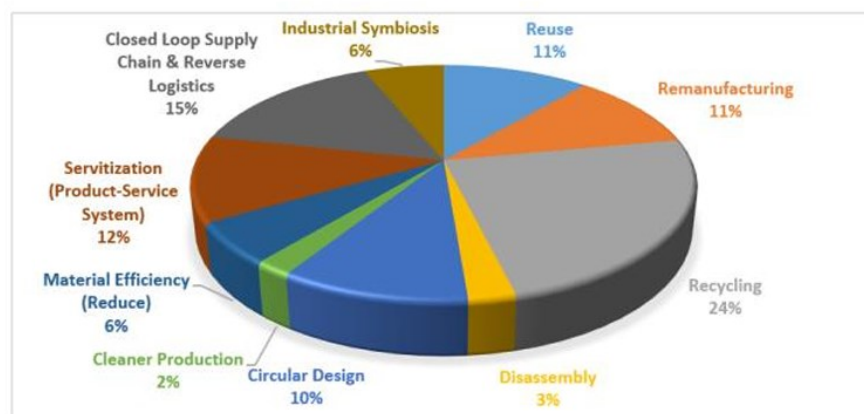


Figure 2: CE strategies adopted by manufacturers

Source: Acerbi F., Taisch M., 'Circular Economy in the Manufacturing Sector as Enabler of Sustainable Manufacturing'

In conclusion, all these above-listed strategies demonstrate the various opportunities that the Circular Economy can offer to companies in the manufacturing field. The advantages always fall on the three economic, environmental and social dimensions.

The Circular Economy can be represented as a path through which the manufacturing sector demonstrates to know how to put into practice the objectives of sustainable manufacturing and the achievement of the SDGs. Among the SDGs, the most important are those linked to responsible production and consumption, industrial innovation, decent work and development of sustainable communities and cities.

Acerbi and Taisch propose the interpretation of the Circular Economy as a set of strategies contained within the paradigm of sustainable manufacturing. The focus is mainly on the achievement of the sustainable development goals (SDGs). Sustainable Manufacturing is born from the meeting of two concepts, sustainable development and the triple bottom line. This approach aims to obtain economic, environmental and social results along the entire life cycle of products through the “smart” use of natural resources. Sustainable manufacturing deals with analyzing trends, technologies and methodologies that allow manufacturing enterprises to move from linear models towards circular and sustainable models. Moreover, it includes the capability to design and apply solutions, using typical engineering tools, to sustainable development problems. SM also requires the critical evaluation of the impacts of one's own solutions and decisions, it is necessary to be aware of the consequences of the various design and managerial choices. The various strategies linked to the Circular Economy are interpreted by the authors as a subset of those of sustainable manufacturing. They are feelable in such a way because they are all united by the same general objective, namely sustainable development in manufacturing. The subset shares the objective of closing resource loops, reduction of virgin materials consumption, reduction of

waste and regeneration of materials. (Garetti & Taisch, 2012) (Taisch & Acerbi, n.d.)

The Circular Economy, therefore, acts as an “enabler” of sustainable manufacturing, it translates the general principles of sustainability into a set of concrete principles and strategies for the manufacturing industry. On one side, it helps enterprises to understand where they can intervene, whether on the product, on the process or on the supply network in order to reduce impacts and waste. On the other side, it offers organizational and business models that allow the enterprise to convert its own choices into concrete economic results and new jobs. The strategies of Circular Economy do not replace Sustainable Manufacturing, but strengthen it. They allow to obtain simultaneously environmental, economic and social performances, providing the manufacturing sector with the means to align itself with the principles of sustainability and the SDG targets. (Kirchherr et al., 2017)

Despite the Circular Economy being represented as something capable of translating the ideals of sustainability into real corporate processes, the literature highlights a series of conceptual and practical limits. These limits emerge especially if one talks about Sustainable Manufacturing. On one side, the various definitions of Circular Economy tend to emphasize only some dimensions, neglecting others such as social equity, future generations, roles and responsibilities of consumers. On the other side, the tools used to measure circularity can present important gaps. These are connected to energetic and toxicological impacts, creating the risk of making choices apparently sustainable, but in reality dangerous. (Brändström & Saidani, 2022; Kirchherr et al., 2017; Taisch & Acerbi, n.d.)

Kirchherr et al. demonstrate how, out of 114 analyzed definitions, almost all say different things. Therefore there is not a single shared idea of

Circular Economy. 95 definitions are substantially different among each other, they do not have a combination (R principles, perspectives, aims, enablers) that appears in more than half of the cases. The CE, in these definitions, is often described through the 3Rs and often reduced also to only one of these Rs, namely that of Recycling. The references to profound changes and to sustainable development remain the minority. The authors, therefore, make reference to the “Circular Economy babble”, namely the definition of a concept through different ways and that do not have points in common. This leads to losing scientific coherence and to the risk of the collapse of the concept itself, becoming difficult to use.

Through a quantitative analysis, the idea that the CE is only referred to the environment is disproved. In the various definitions, the most cited dimension is economic prosperity, followed by environmental quality. Among those less mentioned instead there are social equity and references to future generations. The Circular Economy, therefore, is associated more to strategies of growth, efficiency and reduction of impacts, than to social and generational instances. This disparity is very relevant for Sustainable Manufacturing, given that it should pursue in parallel economic, environmental and social objectives.

Both Kirchherr et al., and Acerbi and Taisch, highlight that the social dimension of sustainability is the most neglected within the field of Circular Economy of the manufacturing sector. Social equity, which includes well-being, employment and social justice, is mentioned only by a small quota of definitions. The reference to future generations, instead, appears only in one single definition out of all those analyzed. Acerbi and Taisch demonstrate that the majority of works on CE demonstrate that strategies converge more on environmental and economic impacts than on social aspects and “people-oriented” SDGs (SDG 2, 3, 4, 5).

Given the low attention on these themes, the Circular Economy presents itself as a techno-economic change. In practice, it offers new business

opportunities, optimizes the use of resources, but themes such as employment condition, the distribution of value along the supply chain and the impact on territorial and community contexts remain excluded. In Sustainable Manufacturing, this gap represents an important limit. A circular model that aims at sustainability should integrate (in the design of products and processes) the environmental and financial dimension with the ethical and social one, guaranteeing social equity, labor protection and long-period well-being for the community. (Kirchherr et al., 2017; Taisch & Acerbi, n.d.)

The studies of Kirchherr et al. bring to light another problem, the limited explicitation of the waste hierarchy, but also of business models and consumers as enablers of the CE. From the analyses, moreover, it emerges that approximately one third of the examined definitions presents a hierarchy among the different R strategies. The percentage reduces even more if one talks about documents drafted by practitioners. A gap compared to the literature on cradle-to-cradle and on waste management is therefore highlighted. It is emphasized indeed that upstream interventions like reduction and reuse have a priority compared to mere recycling and energy recovery. The lack of a hierarchical order makes the Circular Economy an inclusive paradigm but deprived of selection capacity. There will be therefore ample space for minimal interventions (such as the increment of the recycling rate) labeled as “circular”, which will not lead to structural rethinkings of products, processes and value chains. (Kirchherr et al., 2017)

Despite much literature relative to the CE focuses on circular business models, only few analyzed definitions make reference to these as a central element. An even lower number cites the concepts of consumers or consumption practices. There is therefore an unbalanced vision, one focuses especially on how enterprises produce and looks less at how

people or clients buy and use products. The majority of the definitions of CE analyzes what happens inside the enterprise and along the value chain. What is not included are the demand, consumption behaviors and the acceptance of circular business models. In Sustainable Manufacturing, this is a relevant limit. Without the active role of consumers and innovation in one's own business model, circular strategies risk not being implemented. Consequently, it will not be possible to revolutionize the modalities of design, utilization and end-of-life management of goods. (Kirchherr et al., 2017; Taisch & Acerbi, n.d.)

Parallel to the theoretical criticalities examined so far, from the literature also emerge limits relative to the plane of measurement. The main circularity indicators at the micro level (product), according to Brandström and Saidani, focus on material flows and on the dynamics of closing, slowing and narrowing. These metrics manage therefore to collect only in part the impacts linked to energy consumption and toxicity. In the case study reported by the authors, several CE strategies applied to the supply chain of a lawnmower are analyzed. In this analysis, four circularity metrics are put in comparison with three LCA impact categories (Global Warming Potential, Material Resource Scarcity, Human Non-Carcinogenic Toxicity). The results show a satisfactory alignment between metrics and resource scarcity impacts, but discrepancies are present on the climate and toxicological front. This divergence results especially marked in scenarios characterized by a high energy intensity. The metrics that make reference to materials tend to reward those strategies that reduce the consumption of raw materials and waste production. On the contrary, they show a weakness in evaluating energy trade-offs and the toxicological impacts generated. A scenario that favors recycling or the extension of the life of a product can result very circular

according to material efficiency KPIs, even if they generate a greater energy consumption or carbon footprint. (Brändström & Saidani, 2022)

The authors conclude that circularity metrics, by themselves, are not efficient tools. By themselves they are not enough to guarantee that the adopted CE strategies lead to an effective global environmental benefit. In order to avoid burden shifting phenomena, in which a certain type of impact is reduced by increasing others, circular metrics should be used in combination with LCA and with broader evaluations. For the manufacturing sector it is a relevant criticality. Many circular strategies, such as remanufacturing, advanced recycling or servitization, require further processes and reverse logistics. Consequently, maintenance and repair activities will be more intensive from the energetic and logistic point of view compared to traditional models. The risk is therefore that of promoting non-suitable solutions if the evaluation is limited to measuring the degree of circularity. In fact, even if resource cycles are closed, these might not represent the best compromise neither from the environmental point of view, nor from the social one.

From the analyses of Kirchherr et al., from Acerbi and Taisch and from Brandström and Saidani, emerges that the Circular Economy cannot be used as a synonym of sustainability within the manufacturing field. It must be interpreted as a set of enabling tools, whose benefits are however subject to limits and conditions. On the theoretical plane, there is the necessity to make clearer the link between CE and sustainable development. The CE is not a simple set of practices based on the 3Rs, but a paradigm that operates on various levels (micro, meso, macro). It should therefore contribute to the development of the three dimensions of sustainability, including also future generations.

On the methodological plane, there is the need to develop systems of indicators, given that circular ones by themselves are not enough. These

systems must enclose inside them both circular indicators, and LCA tools and social metrics. Through these combinations, misinterpretations (based on a single dimension) can be avoided and the risk of shifting impacts from one area to another reduced (burden shifting).

For manufacturing enterprises, this means that the CE cannot reduce itself to an optimization of material flows or to an increment of recycling rates. On the contrary, companies will have to ask themselves which circular strategies, which supply chain models or business models generate real improvements on all dimensions of sustainability. The Circular Economy, therefore, has the role of driver or enabler of Sustainable Manufacturing. This is effective only if the circular paradigm is integrated inside a broader framework that recognizes its limits and simplifications. Consequently, it becomes necessary to flank these strategies with tools and metrics capable of intercepting the risk of burden shifting, guaranteeing a balance between economic, environmental and social objectives. (Brändström & Saidani, 2022; Kirchherr et al., 2017; Taisch & Acerbi, n.d.)

CHAPTER 2

2.1 Shareholder, Stakeholder and Stewardship: the evolution of Governance towards the Circular Economy

2.1.1 Shareholder Primacy

In the debate on the purpose of the firm, the shareholder primacy constitutes the starting point with which all other theories must confront themselves. This theory is based on the concept according to which the enterprise is, first of all, property of the shareholders. The management must therefore act as their agent maximizing the value of the invested capital. In this view, the other subjects involved (workers, clients, local communities, environment) play a purely instrumental role. They are considered as a mean to achieve the true objective: the generation of profits for the owners. (Friedman, 2007)

The most important perspective is that of Milton Friedman, presented in the 1970 article titled “*The Social Responsibility of Business is to Increase its Profits*”, published by The New York Times Magazine. Friedman contests the very notion of corporate social responsibility. He affirms that responsibilities belong to natural persons, not to abstract organizations. So the management must not shift its own focus onto objectives different from profit. In a system characterized by free enterprise and private property, the chief executive officer is an employee of the owners. His primary responsibility is directly to them. He deals with managing the enterprise according to their desires, which in the majority of cases translate into “maximizing economic profit, respecting the basic rules of society, those established by law, but also by ethics”. According to Friedman, talking about social responsibility of the manager means asking this subject to act in a way not compliant with the interest of the owners. For example, financing the reduction of emissions beyond the legal limits means diverting the funds of shareholders, clients and employees towards

objectives of environmental policy. Friedman highlights how such expenses, if deprived of an internal economic justification, exceed the boundaries of the duties of management. Under this profile, the chief executive officer exercises functions assimilable to state ones. He imposes private “taxes” in the form of lower profits, higher prices or rather lower salaries (hiring less qualified workers). Another state-like function he exercises is deciding how to allocate resources. For Friedman, this expansion of the roles of management is “subversive”. It wants to replace gradually market dynamics with opaque political logics deprived of a real control. (Friedman, 2007)

The author reaches his famous conclusion. The only true social responsibility of the firm coincides with the maximization of profits for the shareholders. This economic objective is not, however, absolute. Corporate action must indeed rigorously respect the rules of the market, operating within an open, transparent competition deprived of fraudulent or deceptive dynamics. From this derives a monocentric conception of corporate purpose. Other objectives (environmental, social, and of collective well-being) are considered legitimate only if pursued in the private sphere of the individual or if they offer an indirect contribution to the maximization of profits. (Friedman, 2007)

2.1.2 Stakeholder Theory

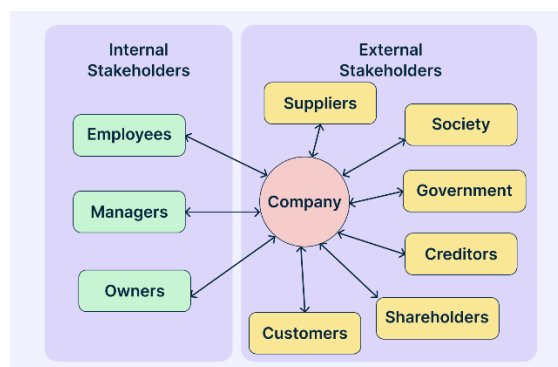
As an alternative to the shareholder-centric theory, the stakeholder theory proposes a vision of relations between different subjects who have an interest (*stake*) in the business activity. Among these are included not only shareholders, but also customers, suppliers, employees, the community, creditors, institutions, the environment, and many others. According to this perspective, the focus is no longer solely on profit maximization for shareholders. The main objective becomes the creation and maintenance of relationships with the entire stakeholder ecosystem. The success and

long-term survival of the enterprise depend in fact on the support and consensus of the subjects involved. (Athuraliya, 2024) (Freeman & McVea, 2001)

Freeman and McVea, in their 1984 work, “*A Stakeholder Approach to Strategic Management*”, reconstruct the evolutionary path of the idea of stakeholder management. They, furthermore, also highlight its main characteristics. In the first place, the aim is to define corporate strategy based on concrete subjects with “names and faces”, overcoming generic categorization. It is not sufficient to speak of customers, employees, or shareholders in an abstract way, but a deep understanding of the various characteristics is required. Concreteness becomes a fundamental requirement. Attention shifts from the general behavior of the average consumer to the needs of the specific customers of the firm. Elements such as the relational background, expectations, and commercial constraints become the true decision-making drivers. In second place, the stakeholder theory presents a dual nature, both descriptive and prescriptive. It describes that firms operate in complex relational networks with multiple stakeholders. At the same time, it highlights that a good strategic management should actively design and influence relationships with such subjects, rejecting a passive role. This process leads the management to have to foresee the impact of its own decisions on stakeholders. This contributes to the objective of creating the future scenario in which the firm will find itself competing. (Freeman & McVea, 2001)

Finally, according to this theory, separate strategies will not be created for each stakeholder group, with the risk of focusing only on the interests of one category. The management must implement actions that aim to simultaneously take into account various perspectives. The researchers Freeman and McVea, however, recognize that it is not always possible to create situations in which all stakeholders “win”. Truly effective strategies

will be those that manage to distribute benefits and sacrifices equally in the long term. Only in this way the firm will be able to maintain the consensus of key actors, indispensable for the continuity of its own business. Stakeholder management is therefore seen as a tool that offers the management a broad range of strategic solutions. This approach allows corporate decisions to be based on a network of continuously evolving relationships, fundamental for maintaining credibility and the capability to remain on the market. (Freeman & McVea, 2001)



Source: <https://creately.com/guides/stakeholder-theory/>

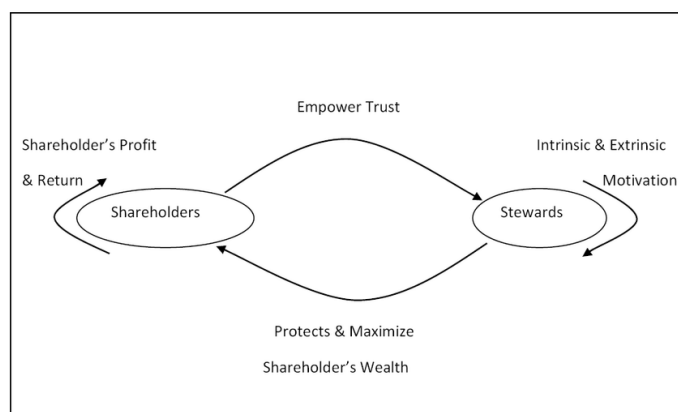
2.1.3 Stewardship Theory

Developed by researchers Lex Donaldson and James H. Davis, the Stewardship Theory detaches itself from the assumptions of neoclassical economics. It rejects the conception of the manager as “*homo economicus*”, namely a calculating, individualistic actor guided by opportunistic ends. On the contrary, the theory is based on the model of the “steward”. In this vision, the manager is seen as an actor motivated to operate as a responsible steward of corporate resources and heritage. According to these premises, managerial conduct is not necessarily guided by egoistic interests. Their scale of needs is represented by psychological models such as Maslow's pyramid and the self-determination theory. These frameworks demonstrate that self-actualization, recognition, and the sense of belonging are realized through the achievement of corporate objectives. (Ungvarsky, 2020) (Donaldson & Davis, 1991)

Stewardship Theory is proposed as an alternative to Agency Theory. The latter claims that managers act as opportunistic actors who only want to maximize their own profit. They are agents who need constant monitoring and monetary incentives, indispensable to align corporate decisions toward the maximization of shareholder value. In the work “*Stewardship Theory or Agency Theory: CEO Governance and Shareholder Returns*”, Donaldson and Davis compare these two models. Agency theory sees a conflict between owners (principals) and managers (agents) and hypothesizes the existence of “*agency loss*”. This expression describes a loss of value on the part of shareholders due to the fact that managers pursue objectives different from those of the owners. From this problem derives the introduction of control mechanisms (independent boards of directors, separation of the role of chairman and CEO, and many others) designed to limit managerial egoism. The Stewardship theory, on the contrary, maintains that managers and owners are intrinsically aligned. Even in the case in which divergences emerge, stewards will tend to prioritize cooperation over conflict. They recognize that the benefits deriving from collective success are superior compared to the immediate ones coming from egoistic behavior. Consequently, there will be no need for stringent controls, but rather for partnership, reciprocity, and ethicality. When executives have a strong connection with the firm (by virtue of a long tenure or their role in shaping form and strategy), their personal interest merges with that of the organization and shareholders. The central problem will therefore be to understand how to place the executive within an organizational and governance structure to foster good corporate results. (Donaldson & Davis, 1991; Ungvarsky, 2020)

The Stewardship Theory, moreover, flips the traditional guidelines of Agency Theory. The latter requires the separation between the position of Chief Executive Officer (CEO) and that of Chairman of the Board of

Directors to guarantee independence in control. The Stewardship Theory, instead, says that the coincidence of the two roles (CEO Duality) is fundamental to maximize shareholder returns. Reuniting the two figures avoids ambiguity and conflicts of authority. Unlike Agency theory, the Stewardship Theory requires a board of directors composed for the most part of internal members (insiders). These subjects are considered more effective stewards who are better prepared to support the management. External members often possess scarce knowledge of daily operations. Organizational models, therefore, must not be based on an oppressive hierarchical control, but on flexible models. These must foster autonomy, empowerment, and proactivity of the management. (Donaldson & Davis, 1991; Ungvarsky, 2020)



Source: https://www.researchgate.net/figure/Stewardship-theory-model_fig3_273743680

2.2 Comparison among Shareholder Primacy, Stakeholder Theory and Stewardship Theory

From the comparison among the various theories emerges a clear separation between the logic of Shareholder Primacy and those of Stakeholder and Stewardship. A certain complementarity between Stakeholder Theory and Stewardship theory can, however, be highlighted. For Friedman, the firm is solely a mean to maximize the profit of shareholders and the management is an agent subordinated to this objective. Social and environmental purposes remain excluded from this

vision, except in cases where they are imposed by law or directly useful for profit. The Stakeholder Theory criticizes this monocentric logic, saying that reality is represented by modern firms embedded within complex relational networks. The omission of needs and expectations of other subjects, caused by strategic choices, risks undermining the credibility and survival of the firm. The Stewardship theory maintains value creation as a reference, but proposes an image of the manager as a steward of corporate heritage and not as an “internal enemy”. (Athuraliya, 2024; Donaldson & Davis, 1991; Freeman & McVea, 2001; Friedman, 2007; Ungvarsky, 2020)

Each approach simplifies a different aspect of reality. None of these theories will be sufficient alone. The Shareholder Primacy specifies the responsibility of management toward those who invest capital. On the other hand, this approach risks transforming the firm into a mere tool for financial value extraction, neglecting the relationships deriving from economic activity and the presence of various interests of the subjects involved. The Stakeholder Theory corrects Friedman's “error”, putting at the center everything that the previous theory had ignored. Questions open up, however, on the way management decides which priorities to follow when these are in conflict with one another. This model leaves freedom of choice in establishing what importance to give to the different stakeholders. The Stewardship Theory highlights motivational dimensions usually neglected, proposing governance models that are based on trust and a sense of belonging. However, there are limits because it is assumed that the objectives of managers and the company are always aligned. This hypothesis could reveal itself to be incorrect in various situations and phases of corporate life. Indeed, instead of choosing which theory is the most correct, one should consider the strengths and limits of each simultaneously. In this way, the three visions can be used in a

complementary manner to analyze reality from various points of view. This helps to understand who truly has a right to corporate results, how the role of executives is viewed, and which interests (both in the immediate term and in the future) are favored. (Athuraliya, 2024; Donaldson & Davis, 1991; Freeman & McVea, 2001; Friedman, 2007; Ungvarsky, 2020)

2.3 Implications for sustainable manufacturing and circular economy in the manufacturing sector

In their study, Sjøfjell and Taylor demonstrate that Shareholder Primacy is not a legal obligation, but a cultural habit that has caused the true nature of the firm to be forgotten. Indeed, the firm no longer has as its main objective the creation of well-being and utility for the collectivity, but the sole gain of investors. Law, habits, and markets create the mechanism of “regulatory ecology” which pushes companies to ignore social and environmental damages and to go against international agreements (such as SDGs or climate agreements) just to make a profit. However, the evolution of the macroeconomic and scientific context highlights the presence of a link between climate/environmental risk and financial and business risk. (Sjøfjell & Taylor, 2019)

Sustainability directly impacts the economic results of the company due to three typologies of risk: physical risks, transition risks, and liability risks. Consequently, the lack of consideration of ecological and circular factors exposes the management to possible lawsuits for breach of their duties (“*duty of care*”). (Ferran & Schilling De Carvalho, 2025)

Sjøfjell and Taylor emphasize that Shareholder Primacy induces the board and management to prioritize short-period objectives. In this sense, Shareholder Primacy acts as a “barrier to sustainable companies”. It makes sustainability be perceived as an additional cost as long as it is believed that the sole objective is to increase shareholder return. (Sjøfjell & Taylor, 2019)

In this framework, trying to reconcile circular economy logics with Shareholder Primacy results difficult in the short period. This leads to the reduction of investments in product redesign, material recovery, and long-term process innovation. From here, a first link between long-period objectives, typical of the circular economy, and managerial duties is created. (Ferran & Schilling De Carvalho, 2025; Sjøfjell & Taylor, 2019)

The Shareholder Primacy incentivizes firms to offshore production and sourcing, when combined with globalization and the structure of corporate groups. This behavior leads to a lowering of enforcement risk and costs in the short period. The management tends to consider the environmental and social damages of the supply chain as simple *negative externalities*. These are costs that weigh on society and not on the corporate financial statements; in this way, the maximization of shareholder return is not undermined.

In parallel, the diffusion of disclosure obligations, transition plans, and reporting standards increases transparency along the supply chain. This clarity fuels forms of private enforcement, pushing boards to consider the risks linked to emissions, modern slavery, corruption, and other ESG criticalities in global supply chains more seriously. The principle of maximization of shareholder returns must be replaced or corrected by a legal obligation of sustainable value creation. The law must oblige managers to pay for environmental damages, thus *internalizing the costs*. In this way, sustainability transforms into a duty and no longer a secondary choice. (Ferran & Schilling De Carvalho, 2025; Sjøfjell & Taylor, 2019)

Sjøfjell and Taylor recall that large enterprises dominate key sectors such as energy generation, manufacturing, and production, operating beyond the physical limits of the planet. In a context where Shareholder Primacy dominates, factories continue to use large quantities of materials and energy just to cut costs in the short period.

To solve this problem, a reform of company law is proposed. It provides as corporate purpose the respect for planetary boundaries and the social foundation. In this way, sustainable manufacturing obligatorily becomes part of the business model and no longer voluntary CSR. The board will be forced to put sustainability within risk management and into performance indicators. (Ferran & Schilling De Carvalho, 2025; Sjøfjell & Taylor, 2019)

Three elements place pressure on directors: information transparency, liability risk (with the consequent fear of ending up in court and having to pay eventual damages), and the obligation to possess ESG competencies. These three factors push managers to reason about their long-term choices on circular economy, supply chain, and sustainable manufacturing. However, they find themselves in a system that continues to prioritize shareholders. (Ferran & Schilling De Carvalho, 2025)

The Stakeholder Theory offers instead various interpretations to understand how and why firms in the manufacturing sector adopt sustainability practices in their operations. The firm is intended as a set of stakeholders: customers, suppliers, employees, regulators, and shareholders. They form various expectations which, when they concern environmental themes, no longer linger on sole policy. They translate into pressures aimed at the modification of production processes, product design, and supply chain management. Yu and Ramanathan show that these pressures push firms to develop an internal green management. The latter integrates environmental objectives, management systems, dedicated structures, and training. This model makes possible the adoption of green product and process design practices (such as eco-design, reduction of waste and emissions, energy efficiency), leading to positive implications from the environmental side. In other terms, therefore, stakeholder pressures do not determine an immediate shift to green

manufacturing. The new habits will then lead the firm to convert industrial processes into sustainability objectives. (W. Yu & Ramanathan, 2015) (Bello-Pintado et al., 2023)

However, such dynamics do not manifest uniformly within a sector or industry. Various empirical evidence at the manufacturing plant level demonstrate that stakeholder pressures do not have the same intensity or efficacy. They vary based on the characteristics of the sector of belonging and of the facility. In this regard, the study by Bello-Pintado, Machuca, and Danese demonstrates that the adopted sustainability practices do not constitute a single block. They comprise internal initiatives (monitoring, prevention, and process improvement) and external initiatives of collaboration with suppliers. In addition to sectoral specificity, different stakeholder groups play distinct roles in determining sustainable practices. Among internal stakeholders are found top management and employees, whereas to the group of external stakeholders belong customers. These subjects usually push toward a broad and effective implementation of green measures. The reactions of firms are therefore not monolithic, but are rather shaped based on the stakeholder group deemed most relevant. (Bello-Pintado et al., 2023)

It is furthermore necessary to consider the distinction made by Betts et al., which concerns static and dynamic industries, based on the concept of industry clockspeed. Industries operating in dynamic sectors experience greater pressures from primary external stakeholders, such as customers and suppliers, and secondary ones, such as competitors, media, and NGOs. Industries operating in stable sectors do not suffer from these pressures instead. In high-speed contexts, such pressures exert a more marked impact on the choice and intensity of the adopted green strategies. At the institutional and geographical level, Bello-Pintado et al. highlight that pressures on sustainability practices by top management, customers, and

employees are similar both in developed and emerging countries. This confirms the tendency toward global convergence within the scope of sustainability practices in the manufacturing sector. (Bello-Pintado et al., 2023; Betts et al., 2015)

Beyond the pressures deriving from “upstream” suppliers, recent studies highlight the role of stakeholders on the demand side. Du et al. show that CSR policies, if accompanied by a real ecological manufacturing, increase consumers' intention to make green purchases. In traditional manufacturing contexts, sustainability management still follows a top-down direction. The firm undergoes the rules imposed by customers, governments, or the market and transfers them in the form of technical requirements along the supply chain. Fobbe and Hilletoft therefore highlight the transition from a linear economic model to one based on the Circular Economy. Stakeholder engagement as well must be understood as circular, thus transitioning to practices of Circular Stakeholder Engagement. These are based on three types of strategy:

- *Extending the audience of stakeholders* (Extending): beyond customers and suppliers, it is necessary to also involve sub-suppliers, waste managers, end users, institutions, and other actors in one's network. Collaboration with the “value network” (universities, consultants, and start-ups) is likewise important, to manage the technological and cognitive complexity required by circular models.
- *Expanding the object of dialogue* (Expanding): the focus will no longer be solely on the mere reduction of impacts, but circular economy topics (design for reuse and recycling, new business models) are introduced. Sustainability will also become a competence of other corporate functions, not only specialized ones.

- *Leveling up the interaction level* (Leveling up): the circular logic leads to relationships of co-learning and co-creation along the life cycle of the product.

In short, the application of the Stakeholder Theory to the manufacturing sector shows the transition from the simple compliance with environmental regulations to a circular management of production. Sustainability therefore requires the capability to create stable partnerships and networks along the entire production chain. (Fobbe & Hilletoft, 2023) (Du et al., 2024; W. Yu & Ramanathan, 2015)

The Stewardship Theory, at the same time, offers a useful perspective. This model is founded on trust, accountability, and long-period results. The theory is continuing to modify itself to adapt to the growing importance of sustainability management and stakeholder capitalism. The objective is to increase responsibility toward stakeholders (employees, investors, the environment, and communities). In this view, “stewardship-oriented” firms tend to want to align their strategic choices with long-period social, environmental, and economic impacts. Climate risks, such as water scarcity and the increase in the cost of raw materials, are no longer unforeseen events, but are calculated. (Seun & Esther, 2025)

Consequently, it can be said that there is a link between stewardship and ethicality. Top management has the role of guardians not only of financial capital, but also of human and natural capital. The focus must therefore be shifted from the short-term maximization of shareholder value to the creation of multi-stakeholder value in the long term. Governance influenced by Stewardship Theory is therefore useful for addressing the sustainable transition, especially in highly regulated contexts and with growing expectations regarding these issues. (Jide et al., 2025)

In companies such as Unilever, Patagonia, Microsoft, Starbucks, or Danone, executives play an active role in promoting sustainability-oriented business models. They take care of integrating environmental and social objectives into strategy and reporting.

In the case of Volkswagen, the company had a governance not based on stewardship. Priority was given to short-term objectives which, together with the lack of accountability, led to serious environmental violations, reputational damage, and economic losses. The choice to manipulate emissions shattered the trust of the various stakeholders and triggered a very harsh reaction from public opinion. This, in fact, reinforces the connection between the absence of stewardship and business unsustainability. Following the scandal, Volkswagen introduced reforms aimed at building the dimension of stewardship. (Jide et al., 2025)

Overall, the adoption of stewardship, together with CSR and ESG tools, helps reduce the conflict between short-term interests and broad-scope social and environmental objectives.

2.4 Sustainability as a driver of value, performance and competitive advantage

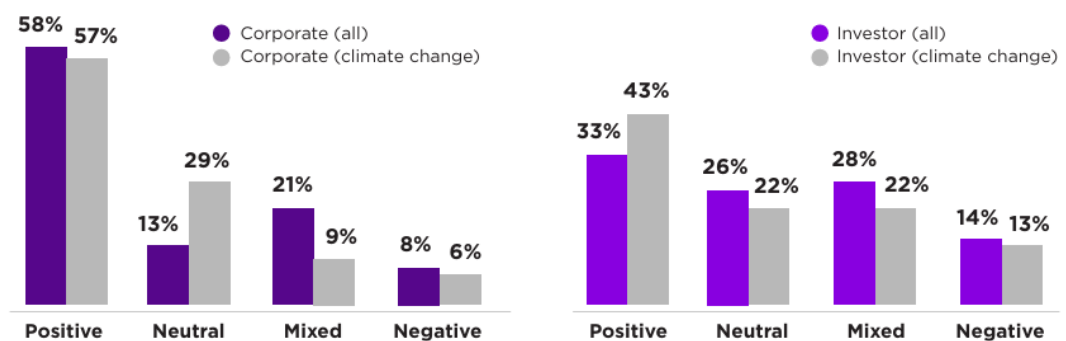
Downstream of the theory presented up to this point, it is necessary to include the economic variable within the analysis. Sustainability is understood as an economic element that can generate risks and costs, but also contributes to the efficiency and competitiveness of the firm.

2.4.1 From risk management to the cost of capital

In recent years, studies have highlighted that a good ESG performance is perceived as a signal of lower risk and better management quality. These effects are measurable.

The NYU Stern Center for Sustainable Business conducted a meta-analysis on over 1000 studies together with Rockefeller Asset

Management. The results found reveal 58% of corporate works showing a positive relationship between ESG and indicators such as ROE, ROA, or stock price. 8%, instead, present a negative correlation. Moving to the analysis of investments, instead, it emerges that 59% of the studies highlight performances equal to or higher than traditional strategies with the same level of risk. This suggests that the integration of ESG factors improves the risk-adjusted returns of investors. (Whelan et al., 2021)



Source: https://www.stern.nyu.edu/sites/default/files/assets/documents/NYU-RAM_ESG-Paper_2021.pdf

Better risk management, greater operational efficiency, drive to innovate, and quality of relations with stakeholders. These are the recurring factors that link sustainability initiatives and corporate results. However, a condition emerges. The benefits will be seen in the long term and especially in contexts where sustainability is integrated into the strategy and not limited to philanthropic CSR. (Whelan et al., 2021)

The present value of expected cash flows, the perception of risk, and the availability of intangibles (reputation, brand, and relational capital) undergo the influence of sustainable practices. According to the DCF (Discounted Cash Flow) perspective, various adjustments occur. The first concerns cash flows; there will be, for example, lower operational costs, lower probability of receiving sanctions or of reputational incidents. The second is represented by a more contained Weighted Average Cost of Capital (WACC) for those firms that are more solid on the environmental,

social, and governance side. Those who evaluate firms (analysts and investors) understand that sustainability is no longer just a matter of image or ethics. It is a variable that can change the financial value of a company. (Nguyen et al., 2025)

Gonçalves et al., analyze firms listed on the STOXX Europe 600 between 2002 and 2018. The data reveal that a solid ESG positioning leads to a lower cost of equity capital. In addition to this, it also helps to attract new capital. The cost of debt, conversely, moves in the opposite direction: it grows as ESG scores increase. Banks and creditors see these initiatives as excessive expenditure, often with a lack of alignment with their priorities (protection of capital). Especially when the company, on average, invests in sustainability much more than its competitors. (Gonçalves et al., 2022)

Markets penalize, on the equity side, firms that are lazy in the implementation of sustainability compared to competitors. On the debt side, creditors increase rates for companies that overdo it with ESG compared to the average. There exists, therefore, an optimal level, in which a company stands in the middle. To minimize the total cost of capital, the firm must position itself around the average of its sector. In periods of financial crisis, the importance of ESG diminishes. Banks and investors have a single concern: immediate liquidity and the risk of a macroeconomic collapse. (Gonçalves et al., 2022)

In brief, the analyses carried out lead to a common point. In the majority of cases, a good ESG positioning is interpreted as better risk management and generation of stable cash flows. This leads to positive effects on return and the cost of equity capital. The cases are, instead, heterogeneous on the debt side. Even in this case, ESG is relevant for the risk-return analysis. It can be affirmed that sustainability is not just accessory, but directly influences the WACC, the net present value of projects, and firm value.

2.4.2 Operational efficiency, circular economy and performance in manufacturing

Beyond ESG criteria, circular economy and sustainable manufacturing practices are important. They lead to better margins, waste reduction, and greater efficiency.

The analysis of 200 European firms conducted between 2018 and 2022 by Shavkatov et al., is very important. An index was constructed, the Circular Economy Index (CEI), which is based on circular design, resource impact, reuse, recycling, and remanufacturing. The results obtained from the study indicate that a 1-point increase in CEI generates an average increase of 0.152% for ROI, 0.087% for the gross profit margin, 0.063% for the net profit margin, and 0.203% for the total shareholder return. The ROI coefficient rises to 0.225 after three years. This means that as the supply chain and products are redesigned, gradual economic benefits are obtained. (Shavkatov et al., 2024)

Panel Data Regression Results (Fixed Effects Model)

Variable	ROI	Gross Profit Margin	Net Profit Margin	Total Shareholder Return
CEI	0.152*** (0.028)	0.087** (0.034)	0.063** (0.022)	0.203*** (0.057)
Firm Size (log)	1.243*** (0.312)	0.756** (0.289)	0.532** (0.201)	1.876*** (0.458)
R&D Intensity	0.328** (0.124)	0.412*** (0.118)	0.276** (0.097)	0.587** (0.223)
Leverage Ratio	-0.843** (0.276)	-0.567* (0.254)	-0.721** (0.238)	-1.132** (0.412)
Constant	-5.876** (1.687)	24.312*** (5.432)	2.987* (1.345)	-12.543** (4.678)
Observations	1000	1000	1000	1000
R-squared	0.342	0.287	0.265	0.318

Notes: Standard errors in parentheses. * - $p < 0.05$, ** - $p < 0.01$, *** - $p < 0.001$.

Source: <https://ea21journal.world/index.php/ea-v207-01/>

At the same time, diminishing returns were found. If there is a very high level of circular implementation, the positive relationship between CEI and profitability tends to stabilize. Beyond this threshold, however, investments bring smaller benefits. This is not the case for everyone, however; there are geographical and size differences. In the high-tech sector, in large enterprises, and in Northern Europe, the advantages are greater. This occurs thanks to a more favorable technological and

regulatory system. The CEI index influences ROI through two channels: increase in brand value and operational efficiency. (Shavkatov et al., 2024)

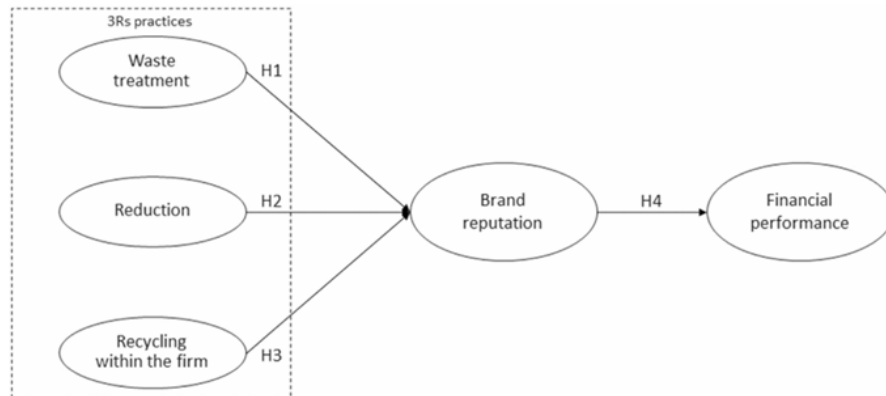
Nonlinear Relationship between CEI and ROI

Variable	Coefficient	Std. Error
CEI	0.287***	(0.062)
CEI ²	-0.002*	(0.001)
Control Variables	Included	
Observations	1000	
R-squared	0.358	

Note: * - $p < 0.05$, *** - $p < 0.001$.

Source: <https://ea21journal.world/index.php/ea-v207-01/>

Moving to Italy, Mazzucchelli et al. took a sample of 404 large manufacturing firms. CE practices based on the 3Rs are analyzed as sustainable managerial strategies. Through a statistical model (SEM), it is analyzed how these actions impact brand reputation and financial profitability. The results demonstrate that reputation acts as a bridge between sustainability and monetary return. (Mazzucchelli et al., 2022)



Source: <https://onlinelibrary.wiley.com/doi/10.1002/csr.2298>

The circular economy in the Italian landscape operates according to two modes. The first concerns the containment of costs related to inputs and waste management. The second is the building of the reputation that will lead to increases in demand, pricing power, and stakeholder loyalty. Waste management and recycling, therefore, strengthen the reputation of the firm and, consequently, economic results. Strategies related to Reduction, instead, impact directly on ROI and margins, reducing waste and inefficiencies. This mode of operating is vital for manufacturing firms that

have an intense use of resources. In these, the transition from the linear "*take-make-dispose*" model to circular models occurs, impacting both on the economic and on the reputational side. (Mazzucchelli et al., 2022)

The study on 308 Chinese manufacturers by Yu et al., provides other valuable data. Two levers of circular economy are distinguished: ecological design and investment recovery. The first occurs in the initial phases of the product life cycle and concerns the design of processes and products that minimize materials, energy, and environmental impacts. The second regards the recovery of value in the final phase of the product life cycle through reuse, resale, and reconditioning. Through a structural equation model, it emerges that both practices improve corporate accounts. Firms that act in an ecological way are, therefore, inclined to obtain better environmental results and develop innovative capabilities that will lead to economic growth. (Y. Yu et al., 2022)

The message left is clear. Manufacturing firms that adopt circular economy and sustainable manufacturing practices systematically improve their economic-financial results. This occurs through the mix of cost reduction, efficiency, growing reputation, and new capabilities. The circular transition is, therefore, not to be considered only as waste reduction. It feeds the innovation of the manufacturing firm in its entirety.

2.4.3 Green innovation and competitive advantage

Even when translated into eco or green innovation, sustainability acts as a reinforcement in the long term.

The literature regarding this topic has always provided heterogeneous results, both positive and negative, and sometimes even null. Zheng and Iatridis have developed an analysis across 35 countries involving approximately 124,000 firms. In their study, they analyzed 5 typologies of eco-innovation and 4 forms of performance. The 5 ecological categories

are: eco-process innovation, eco-product innovation, eco-technological innovation, eco-management innovation, and other eco-practices. The performances, instead, include: the economic, environmental, operational, and social dimensions. (Zheng & Iatridis, 2022)

Overall, there appears to be a positive association between firm performance and eco-innovation. The correlation is equal to approximately 0.33: this means that firms that are more attentive on the green side obtain better results compared to those that are less attentive. The impact is maximum when it concerns the environmental side (approximately 0.53). It is intermediate on the operational and social level (0.44 and 0.51). Instead, it will be contained on the economic-financial dimension (0.20).

Not all forms of eco-innovation give the same contribution. Eco-product innovation offers the best response. Eco-technology innovation, instead, gives a weaker feedback. This derives from the fact that technological investments require various organizational adjustments before producing concrete results. The context also influences the results. In the manufacturing sector, the effect will be more marked on all fronts compared to the service sector (effect only on social performance). The same thing applies to developing countries compared to more advanced ones, and also to SMEs rather than large enterprises. (Zheng & Iatridis, 2022)

These findings make it clear that competitive advantage depends on how the company intends to act and innovate, and not only on attention to the environment.

In his research, Becker analyzes a set of Spanish manufacturing and service companies (2008-2016). Through propensity score matching, a comparison is made between those who use green innovation strategies and firms that do not use them. The purpose of this verification is not so

much to demonstrate whether green innovation directly increases turnover or not. It will instead be to understand how much of this turnover derives from revenues from innovation, such as, for example, the creation of new products not present on the market (*new-to-market*).

From the data, it emerges that, all other conditions being equal, firms that pursue green innovation have approximately between 3.1 and 4.1% more turnover deriving from new products compared to firms that are not green innovators. It is the proof that ecological orientation accelerates innovation.

New-to-firm products, that is, innovative but imitative ones, do not bring the same advantages. They risk leading to a reduction in the share of turnover if combined with certain green product innovation strategies. This indicates that there is a need for radical choices that stand out. (Becker, 2023)

If one looks at the overall financial statements of the company, neutrality emerges from the data in the short term. Improvements in labor productivity are slight. On the side of employment and total turnover, a relevant variation does not emerge. From this, a very precise idea is outlined. In evolved markets, green innovation will have effects on competitive repositioning and on the offer. It will not, instead, have an automatic effect on traditional indicators, which will improve at a later stage. It can be said that the differences between green innovators and conventional innovators consist, if they exist, in small increases in performance, such as labor productivity. The element capable of turning things around resides in the ability to bring disruptive solutions to the market. (Becker, 2023)

The review by Qiang and Yang interprets these data according to the *Resource-Based View* (RBV). What is meant by green innovation? The authors define it as a set of products, processes, and management systems

that optimizes the use of resources and reduces emissions. The objective of this practice is to generate economic, environmental, and social benefits. These combinations push the firm to adopt low-carbon industrial systems.

There exist three pillars that explain how and why green innovation influences corporate results. The first is the *cost-benefit approach*, linked to the cutting of environmental costs and the development of new revenues. The second is the *theory of reputation*, centered on the consolidation of reputation through the trust of key stakeholders. Finally, the third is linked to *ecological modernization*. It consists in generating, through ecological practices, valuable, rare, inimitable, and non-substitutable (VRIN) resources. (Qiang & Yang, 2023)

Product, Process, and Management give a complementary contribution to green innovation. Product innovations insert ecological criteria into design and life cycle. Process innovations optimize efficiency and regulatory compliance with effects on costs and the environmental and social dimension. Finally, at the management level, action is taken on learning and coordination, thus creating green supply chains, cost management, or sustainable marketing. (Qiang & Yang, 2023)

Green innovation must therefore be understood not as a set of isolated projects, but must instead be a distinctive element for the company. The latter must exploit it as a lever to differentiate itself and derive an advantage. Empirical evidence, in fact, demonstrates how positioning is strengthened first and only subsequently the general results of the company.

2.4.4 Limits

Although up to this point positive data have been encountered almost always, there are studies that also highlight limitations.

The problem arises in emerging markets. A meta-analysis of 52 studies concerning Indonesian companies (2019-2024) shows that ESG disclosure has a contained and not statistically significant effect. The results are heterogeneous and the authors interpret them as a sign of environmental practices implemented only for mere compliance. In fact, many times it happens that companies have to report only to satisfy bureaucratic requirements (*bureaucratic greenwashing*). The quality, accuracy, and consistency of the information could therefore be insufficient. This also explains why these companies are not rewarded. Markets and investors do not find a real, solid, and measurable commitment, but only a token compliance that does not justify, precisely, a reputational or economic premium. (Prayogo et al., 2026)

A more general study on ASEAN countries detects problems in those contexts characterized by weak regulations, risk of greenwashing, and short-term orientation. A negative relationship is identified between ESG scores and the market value of the firm (Tobin's Q). The environmental and social components reduce firm value, while the governance dimension has no significant effects. In less evolved countries, investments in sustainability are therefore perceived as an operational cost and not as a competitive advantage. (Prabawati & Rahmawati, 2022)

These criticalities affect Europe as well. In fact, the European Union introduced Regulation (EU) 2020/852 on Taxonomy. This regulation aims to provide an objective measurement of the value generated by companies' sustainable activities. The latter will no longer have to make a voluntary disclosure, but must track KPIs, costs, and revenues. The next chapter will deepen the functioning of the European Taxonomy. Foundations will be provided to understand how manufacturing companies, such as Pirelli, must adapt to align with these increasingly stringent regulations.

CHAPTER 3

3.1 Regulation (EU) 2020/852 and its objectives

The work to establish the *EU Taxonomy* dates back to December 2016. It stems from the urgency to address climate change. In 2015, after the Paris Agreement and the 2030 Agenda, a sustainable development framework was outlined. To achieve these goals, the European Commission assembled a *High-Level Expert Group (HLEG)* during that period. Their task was to elaborate a comprehensive strategy on sustainable finance. In January 2018, the HLEG published the result of its work. At the European level, the aim was to create a classification system to shed light on the green activities of companies. On 24 May 2018, the Commission presented a proposal for a regulation, COM(2018) 353, the purpose was to direct private capital towards sustainable growth. On 11 December 2019, the European Commission took another step, the communication on the *European Green Deal* was published. This macro-plan provides for net-zero greenhouse gas emissions by 2050. Given that public funds alone are not sufficient, the contribution of private investment flows was needed. Consequently, on 18 June 2020, the final act concerning the EU Taxonomy was signed, which was then published on 22 June 2020 in the Official Journal. (European Parliament, 2020) (European Commission, 2019)

The primary objective was to create a *common language*. The absence of a single system and unique metrics has always constituted an obstacle. The effect obtained was that the same activity could be considered green in one context and not in another. This uncertainty created rifts in the market, investors did not want to invest cross-border for fear of incurring high verification costs. All this left room for the danger of *greenwashing*. This practice consists of passing off certain activities or investments as sustainable when, in fact, they are not because they do not comply with minimum standards. Such deceptive behavior reduces trust and distorts

competition. The Taxonomy is therefore introduced to address these information asymmetries. It creates this common language, useful for identifying which activities are environmentally sustainable. (European Commission, 2019) (Spinaci, 2020)

The European Taxonomy is based on six environmental pillars. These are presented in *Article 9 of Regulation (EU) 2020/852*. Each represents an area of intervention and they serve to classify the sustainability of economic activities.

1. *Climate change mitigation*: reduction or prevention of greenhouse gas emissions, favoring a transition towards a low-carbon economy.
2. *Climate change adaptation*: abatement and anticipation of the negative effects of climate risks on economic activities, people or nature.
3. *Sustainable use and protection of water and marine resources*: efficient management of water resources and limitation of the deterioration of marine ecosystems.
4. *Transition to a circular economy*: focused on reuse, recycling and reduction.
5. *Pollution prevention and control*: mitigating harmful emissions, limiting the dispersion of polluting materials.
6. *Protection and restoration of biodiversity and ecosystems*.

According to *Article 3*, certain requirements must be satisfied in order for an activity to be considered sustainable. It must make a *substantial contribution* to at least one of these objectives. Second, it must respect the *DNSH (Do No Significant Harm)* principle. Finally, the activity must be carried out in full compliance with *minimum safeguards* and be compliant with *Technical Screening Criteria*. (European Commission, 2019) (Spinaci, 2020) (Lucarelli et al., 2023)

3.2 Alignment criteria: how an economic activity is assessed

The European Commission explains that the Taxonomy is a classification system that defines the criteria to achieve net zero in 2050. As previously introduced, the identification of a green economic activity occurs through a very stringent assessment process. This architecture plays a key role in the European framework. It serves to guarantee the comparability of sustainable investments, transparency and the reduction of greenwashing phenomena. Alignment with the Taxonomy will not be possible in case of non-compliance with one of the previous requirements. (European Commission, 2019)

The first requirement is *Substantial Contribution*. It is not limited to marginal assessments. A company must generate positive, concrete and measurable impacts with respect to one of the six targets of the Taxonomy. Depending on each pillar, the Commission specifies that there are specific technical criteria defined for each and for each economic activity. For example, as regards climate change mitigation, substantial contribution can be measured. In this sense, an activity will provide for aligning greenhouse gas concentrations in the atmosphere with those defined in the Paris Agreement. The purpose is to limit the temperature increase to 1.5 °C. The actions to be implemented are diverse, ranging from the production of renewable energy to energy efficiency up to zero-emission mobility. (European Commission, 2019; Lucarelli et al., 2023; Spinaci, 2020)

To broaden the scope of action of the Taxonomy, two strategic categories were inserted by the legislator:

- *Enabling activities (Article 16)*: In themselves they are not normally considered ecological, but they allow other activities to make a substantial contribution. An example is producers of technologies or infrastructure to abate emissions of third parties.

However, these solutions must not generate a long-term dependency (lock-in) on polluting structures.

- *Transitional activities (Article 10, para. 2)*: concern those sectors where low-emission and economically accessible technologies do not yet exist. The emissions of such activities must be as low as possible for the specific sector. The pathway towards climate neutrality must be concrete and credible. (European Commission, 2019; Spinaci, 2020)

The second requirement is the *principle of Do No Significant Harm - DNSH*. There is a prohibition, namely that of not harming the other environmental objectives. Having passed the first step, one proceeds to checking this second requirement. The reference Article is 17. This establishes that an activity cannot simultaneously solve a problem and create another. For example, a wind farm is an excellent solution if it is not built by damaging a protected habitat. The guidelines established by the Commission state to monitor indirect and direct effects throughout the entire life cycle of the activity (Life Cycle Assessment). The measurement of impacts must cover every single phase: production, use and final disposal. An activity will risk harming the circular economy if it mismanages materials or if it produces too much waste to be landfilled or burned. (European Commission, 2021) (European Commission, 2019)

To facilitate the application of the principle, the European Commission has developed a *Technical Guidance*. It is a process composed of two phases. The first is a rapid check (*Simplified Approach*). If an activity does not threaten any environmental objective, one moves on. The second phase will be an in-depth analysis (*Substantive Assessment*) that will occur in the event that a real risk is detected. The damage is calculated either in absolute figures or by comparing the data with the baseline scenario

considering the consequences of non-intervention. (European Commission, 2021)

The third step is the *Minimum Social Safeguards*. The regulation provides, in Article 18, that in addition to compliance with environmental requirements, minimum social and governance requirements must also be respected. The purpose is to avoid considering an activity sustainable when it presents critical issues on the labor rights and ethics side. An economic activity with zero emissions and protection of water will not be sustainable if it violates human rights. The standard mandates strictly following the *OECD Guidelines* for Multinational Enterprises and the *United Nations Guiding Principles* on Business and Human Rights. To this is also added compliance with the eight *ILO* conventions. In short: sustainability must move in parallel with social protection and transparent governance. (European Commission, 2019; Spinaci, 2020)

The three previous steps must be strictly put into practice to prevent them from remaining abstract statements, thus leaving room for greenwashing. This task falls to the *Technical Screening Criteria (Article 19)*. These parameters establish the quantitative and qualitative thresholds that each activity must reach to show its substantial contribution and compliance with DNSH. Furthermore, they are based on scientific evidence and on the European statistical classification of economic sectors, known as *NACE codes*. The use of this coding is important. The legislation determines the eligibility of an economic activity (*Taxonomy-eligibility*) by examining up to the fourth digit of the NACE code. Consequently, regulatory uncertainty (*Taxonomy-eligibility uncertainty*) can be reduced by accurately mapping

a sector within these criteria. (European Commission, n.d.-b) (European Commission, 2019; Lucarelli et al., 2023; Spinaci, 2020)

3.3 The three Taxonomy KPIs

Once the structure of the legislation has been defined, it is necessary to understand how to measure the various parameters. Article 8 of Regulation (EU) 2020/852 provides the solution. Reporting across three areas is imposed on non-financial undertakings. They must declare what percentage of their turnover, capital expenditures and operating expenditures comes from Taxonomy-aligned activities. To do this, three key performance indicators (KPIs) will be needed: Turnover, CapEx, OpEx. The old indicators were based only on greenhouse gas emission volumes and water consumption. These, on the other hand, bridge accounting data and sustainable performance data. (Hummel & Bauernhofer, 2024)

Turnover expresses the share of net turnover (revenues) obtained from the sale of products or services associated with economic activities considered sustainable by the legislation. The indicator shows the current level of alignment of the business model with climate objectives. It is demonstrated that companies that generate a large percentage of aligned turnover will have a significantly lower Cost of Debt. These will receive bank loans with lower interest rates and equity return premiums. Companies are therefore less exposed to transition risks in the eyes of creditors. Consequently, investors will perceive greater security. (European Commission, 2019) (Rizzato et al., 2026)

However, this KPI is difficult to modify in the short term. Turnover cannot be changed immediately, given that revenues depend on customers, market and contracts. Consequently, a long time will be required for the transition towards sustainable sales models. (Alessi et al., 2024) (Brabec & Macháč, 2026)

If Turnover refers to the present, *CapEx* looks to the future. This second KPI identifies the percentage of tangible and intangible investments linked to *Taxonomy-aligned activities*. Ostojic et al. point out that a growing CapEx indicates that financial resources are directed towards infrastructure improvements increasingly compatible with taxonomy targets. In many manufacturing sectors, a percentage of CapEx higher than that of Turnover is found. This metric is widely used by investors and funds to conduct assessments (“*due diligence*”) on the transition promises of companies. Alessi et al. highlight that the *ratio between CapEx and Turnover* is often used to measure the *Climate Transition Speed* of a company. A high ratio indicates that the company is investing a lot of money compared to that collected from the green market. It therefore implements a strong strategy in order to reposition itself and transform into a completely sustainable entity. (Alessi et al., 2024; Rizzato et al., 2026) (Ostojic et al., n.d.)

A complex and high-emission sector (“*hard-to-abate*”) can be that of *tire production*. For the latter, the indicator is very important. The sector is characterized by long investment cycles and heavy fixed assets, it is therefore capital-intensive. To identify companies that are still in a transition phase compared to those already aligned, a new index is developed. Rizzato et al. introduce the CapEx Taxonomy Index. When a company demonstrates a high CapEx, but a low Turnover, it means that it is currently investing in its sustainable transition. The dynamic matches with the tire sector. The transformation requires significant initial investments to renew plant and machinery (CapEx) in order to generate future green revenues (Turnover). (Alessi et al., 2024; Rizzato et al., 2026)

The last indicator is OpEx. It defines the share of uncapped direct costs linked to green research and development, building renovation, maintenance and other actions linked to aligned activities. The

functionality of this indicator is to maintain the efficiency of what one already has. By taking the ratio of green CapEx and OpEx, Alessi et al. obtain the degree of Green Long-Termism. It indicates the willingness of a company to accelerate its ecological transition. On this topic, the contribution of Ostojic et al. also emerges. OpEx is defined as a parameter that demonstrates the continuity of corporate commitment, especially in operationally intensive sectors. In these, in fact, there can be periods of standstill in capital investments, but a continuous daily maintenance expenditure is present. This latter fact highlights the continuation of ecological commitment. (European Commission, 2019; Ostojic et al., n.d.) (Alessi et al., 2024; Rizzato et al., 2026)

Nowadays, the reporting of these three KPIs is mandatory. In order to obtain accurate reporting, environmental data should no longer be treated individually, but the collaboration of sustainability departments with management control and the Chief Financial Officer (CFO) is required. Banks and other credit institutions have started to use them as a decision-making tool for granting financing. They have therefore become elements to leverage in order to stand out among the many. (Hummel & Bauernhofer, 2024)

A problem that emerges in the analysis of Hummel and Bauernhofer is the level of information quality. The causes are structural. Adequate infrastructures for data collection are lacking and information systems are not keeping pace. Consequently, reporting remains an “endeavour to comply” and information quality inevitably suffers. (Hummel & Bauernhofer, 2024)

Read together, Turnover, CapEx and OpEx manage to give meaning to the sustainable transition. The first tells where one is. The second where one is going and the third indicates the operational effort implemented.

However, the literature also points out important limitations. The impacts of the Taxonomy remain still little studied. In manufacturing and transition sectors, the measurement of KPIs often depends on non-standardized and difficult-to-retrieve supply chain data, with possible effects on the precision of Turnover, CapEx and OpEx. (Chopra et al., 2024)

3.4 Organizational implications and challenges for the manufacturing sector

Taxonomy reporting does not arise in isolation. This is part of a broader framework of sustainable disclosure. The organizational implications linked to the Taxonomy can be read by referring, first of all, to stakeholder theory. It explains that compliance with Regulation (EU) 2020/852 is not a technical fulfillment, but also a response to the expectations of relevant stakeholders. In order to satisfy their information needs, environmental and circular information is disclosed by companies. Consequently, these obtain consensus and strengthen their reputation, subsequently gaining access to capital. (Hummel & Bauernhofer, 2024) (Vitolla et al., 2023) (Moneva et al., 2023)

The transition does not depend solely on internal practices. On the circular economy front, the focus is on the development of relationships between stakeholders. The CE is understood as an activity aimed at the collective creation of value, based on dialogue, collaboration and ecosystem building. There will have to be cooperation between customers, suppliers, partners and institutions. The CE will therefore not be based solely on the mere management and optimization of material flows. It is therefore necessary to adopt 360-degree engagement models, based on reciprocity, knowledge exchange and collaboration between different industrial sectors. (Civera et al., 2025) (Tapaninaho & Heikkinen, 2022) (Casalegno et al., 2020)

Effective reporting does not look only at the final figure presented in the financial statements. According to recent studies: data sharing, digitalization and coordination between departments and in the supply chain are the useful elements for the creation of precise reports. (Civera et al., 2025)

3.4.1 ESG data collection and the role of software

With the introduction of the EU Taxonomy and the CSRD directive, pure narrative has been put aside. Reporting, nowadays, requires complex procedures, large quantities of data and verifiability. Information density makes the adoption of enterprise software that can map and certify this amount of data mandatory.

In the first year of application of Regulation (EU) 2020/852, Hummel and Bauernhofer took as a sample for their study, 45 Austrian non-financial undertakings subject to the legislation. Through a series of interviews, they were also able to understand how the various companies addressed the introduction of these new obligations. What emerged is an element common to the various companies subject to the study. Almost all companies show the three required taxonomy KPIs, but the qualitative information accompanying these data is reduced to a minimum and poorly detailed. (Hummel & Bauernhofer, 2024)

As previously mentioned, in 2021 companies sought to comply with the legislation, but presented gaps. They did not have an adequate structure for this reporting. Consequently, they could not provide detailed descriptions of methods, processes and classification criteria used. In short, companies sought to meet minimum requirements to avoid going against the Regulation. According to Hummel and Bauernhofer this is the typical pattern of adopting a new law. (Hummel & Bauernhofer, 2024)

Aspect	Evidence in the 2021 sample	Interpretation
Disclosure of the three Taxonomy KPIs (turnover, CapEx, OpEx)	Nearly all firms reported the required percentages in their non-financial statements.	Strong commitment to formally comply with the mandate (“endeavour to comply”).
Level of qualitative detail on the Taxonomy	Narrative disclosure was generally brief and not very specific regarding methodologies, boundaries, and data collection processes.	Disclosure remained largely symbolic; the lack of mature data infrastructure limited the substantive quality of reporting.
Maturity of the reporting infrastructure	Interviews highlighted a lack of dedicated systems and processes to collect, validate, and integrate Taxonomy-related data.	The main weakness was not firms’ willingness to comply, but their organizational and technological capacity to support deeper disclosure.

Source: Binda B., 2026

As long as systems are not adequate, there will be critical issues. It will be difficult to extract useful information for corporate governance and dialogue with investors.

From Hąbek’s point of view, the introduction of the Corporate Sustainability Reporting Directive (CSRD) makes sustainability perceived not as a mere disclosure obligation, but as something that requires a reorganization of corporate management. Introduced in 2022 and applicable from 1 January 2024, it extends the obligations of the old Non-Financial Reporting Directive (NFRD). Firms subject to non-financial reporting increase from approximately 11,600 to approximately 50,000. Among these are large listed and unlisted companies, listed SMEs and

non-EU groups with branches in Europe. At the same time, the publication of sustainability disclosures must take place in XHTML digital format and must have specific tracking codes (XBRL tagging). The whole must be integrated into the European Single Electronic Format (ESEF) financial reporting workflow. This mandate derives from the CSRD, which also introduced the European Sustainability Reporting Standards (ESRS). Before the directive came into force, environmental data were included in the notes to the financial statements and had to be read “manually”. Now they are transformed into tagged digital files, which form a database that can be consulted and downloaded by computers, investor software and European Union algorithms, so as to be able to compare ecological impacts originating from thousands of undertakings. (Hąbek, 2025)

From the point of view of the manufacturing sector, these new rules lead to large volumes of complex data. Data related to greenhouse gas emissions (Scope 1, 2 and especially 3) will have to be tracked, according to Hąbek, along the entire supply chain without letting anything slip through. The same applies to water consumption and stress, waste management and Circular Economy parameters, often combining plant, product and supplier data. In addition to the environmental side, tracking must also be carried out on the governance and social side. Information is requested regarding the workforce (diversity, working conditions, health and safety), risk management along the supply chain (due diligence, audits) and sustainability governance (role of the board, supervision methods, stakeholder engagement). The logic of double materiality drives looking at sustainability from two points of view. The undertaking will have to measure its impact on the environment and society, but it will also have to monitor how ESG risks influence its financial performance. All this information will have to be integrated into advanced risk management and financial planning systems. (Hąbek, 2025)

Information silos are often generated in manufacturing undertakings due to the dispersion of data across various ERP, MES (Manufacturing Execution Systems), EMS (Environmental Management Systems) and other software applications. The CSRD remedies this problem by obliging undertakings to build integrated systems capable of connecting operational, accounting and narrative data. The table below summarizes the expansion of obligations envisaged by the CSRD.(Hąbek, 2025)

CSRD phase	Indicative period	Companies in scope	Implications for data
Launch	From 2024	Large public-interest entities already covered by NFRD	Expansion and standardization of ESG disclosure.
Extension	From 2025	Other large EU undertakings	New companies must build ESG data infrastructure from scratch.
Further expansion	From 2026	Additional companies brought into scope	Reporting processes become more formalized and structured.
Consolidation	From 2028	Large non-EU groups with a significant presence in the EU	Harmonization of data across jurisdictions and alignment with EU standards.

Source: Binda B., 2026

The increasingly stringent requirements linked to transparency, comparability and auditability of data will be impossible to comply with without advanced information systems.

Håbek in his study compares eight information systems according to thirteen different criteria. From the comparison, some categories of key functions emerge. These will be indispensable to bridge the gap created by the new regulations. A summary of the key criteria is shown in the following table. (Håbek, 2025)

Key criterion	Short description	Relevance for Taxonomy/CSRD
Data integration and automation	Connect ESG data from multiple systems and automate collection, consolidation, and normalization.	Creates a stable data foundation for reliable KPI calculation and reporting.
Supply chain tracking	Map suppliers, collect ESG information across the value chain, and manage Scope 3 risks and performance.	Important in manufacturing, where value-chain disclosure is especially demanding.
Emissions calculation and scenario analysis	Support Scope 1, 2, and 3 calculations, different methodologies, and scenario analysis.	Helps move from estimates to more repeatable and verifiable climate metrics.
Compliance and regulatory reporting	Provide CSRD/ESRS templates, consistency checks, digital tagging, and multi-framework support.	Reduces formal errors and structures data for regulators and investors.
Structured and unstructured data management	Handle both numeric KPIs and textual materials such as policies, processes, and narrative disclosures.	Supports the mix of quantitative and qualitative information required under ESRS.
Advanced AI features	Include predictive analytics, anomaly detection, NLP, automatic tagging, and assisted narrative generation.	Improves quality, consistency, and timeliness of ESG reporting.

Source: Binda B., 2026

Håbek also offers a segmentation of solutions between SMEs and large enterprises. Among the tools suitable for small and medium-sized

enterprises are: SmartHead, Envirly or Velma ESG, all characterized by simple interfaces, low costs and functionality aimed only at certain pillars without advanced AI integration. The platforms dedicated to large enterprises, on the other hand, are IBM Envizi and PwC ESG Management Solution, which support several standards simultaneously, large amounts of data and are integrated with ERP/CRM systems (SAP, Oracle, Salesforce and others). (Hąbek, 2025) (Markova-Karpuzova et al., 2024)

Ultimately, it emerges that a “universal” ESG software does not exist. The choice depends on the size of the firm, ESG competencies, supply chain complexity and internal data management. For large international manufacturing companies, it will be mandatory to adopt a complex system given that thousands of ESG data points will have to be aligned with Taxonomy and CSRD. (Hąbek, 2025)

An important role is played by AI and Advanced Analytics. These offer significant help at any stage, from raw data analysis (anomaly detection) to gap analysis against sector benchmarks (comparison with competitors' results). Furthermore, they also analyze stakeholder opinions in interviews and automatically collect metrics from public sources, ERP software and sensors. They also offer the possibility to create a partial narrative and graphic processing of data. Finally, there will be the possibility to cross-reference stakeholder priorities and sector performance to understand which are the priority ESG topics. However, only a few solutions (such as IBM Envizi and PwC ESG Management Solution) offer advanced AI functionality. This software is the only real solution to manage the new regulatory demands. The real challenge will be to understand how quickly undertakings manage to overcome the technological and organizational delay. (Hąbek, 2025) (Markova-Karpuzova et al., 2024) (Visalli et al., 2023)

Through the CSRD, sustainability is now subject to *external assurance*. The directive provides for a gradual path. Initially, data will be subject to limited assurance, but over time standards and verifications mature and, consequently, there is a transition to an audit similar to that of financial statements. Data, for this reason, will have to be traceable backwards, not just calculated. (Håbek, 2025)

According to Hummel and Bauernhofer, it will be necessary to report the composition of numerator and denominator of aligned CapEx and OpEx. It will also be necessary to describe the nature of the economic activities and the methods adopted to avoid double counting phenomena. In practical terms, it will be necessary to know with certainty the origin of the data contained in the KPIs, business units included and excluded and how emissions or consumption are translated into taxonomic economic figures. Traceability is fundamental for auditors. (Hummel & Bauernhofer, 2024)

The challenge, therefore, does not reside solely in the KPI database. Given the ESRS request for numerous qualitative information, it will be in the management of the ESG information life cycle, which must include a wide range of documents and procedures. ESG software therefore intervenes to help create an “audit trail” between operational data, transformation and final disclosure. The following table shows the main elements of this mechanism.

Function	Description	Relevance
Data integration and automation	Data Integration and Automation and automated data collection capabilities that can integrate with existing manufacturing systems.	Supports sustainability reporting by connecting operational systems and ESG data.
Supply chain management	Supply Chain Management and robust supply chain mapping and monitoring capabilities.	Relevant because the CSRD emphasizes value chain reporting.
Emissions calculation and management	Emissions Calculation and Management and engines capable of handling complex Scope 1, 2, and 3 emissions.	Supports emissions reporting and calculation across facilities and product lines.
Regulatory compliance and reporting	Automated report generation, digital tagging capabilities, and audit trail functionality.	Directly linked to CSRD and ESRS reporting requirements.

Source: Binda B., 2026

3.4.2 From the ESG database to taxonomy tracking

The Taxonomy is not created to replace generic ESG KPIs; rather, these serve as a broad and fragmented base to be used for the construction of official Taxonomy KPIs (CapEx, OpEx, Turnover).

The transition from a generic ESG indicator to a Taxonomy indicator is not immediate, as highlighted by Hummel, Bauernhofer and García-Torea et al. It requires an *information engineering* process, relevant activities will have to be selected, technical criteria applied, and numerical and narrative data skillfully managed from different sources. (Garcia-Torea et al., 2024) (Hummel & Bauernhofer, 2024)

ESG KPIs are normally understood as indicators that measure the 3 pillars (environmental, social and governance) that are based on global standards (GRI, ESRS). Market studies show that a good ESG positioning reduces the cost of debt, lowers barriers to capital raising and guarantees a better company valuation.

Taxonomy KPIs measure instead how much of turnover, capital expenditures and operating expenditures is connected to activities considered “aligned”. Article 8 of Regulation (EU) 2020/852 in fact establishes that non-financial undertakings subject to the CSRD must report the previously named indicators.

The difference is evident. The former operate at the undertaking level, showing the combination of various dimensions; the latter act at the level of economic activities, associating each business segment precisely with the relative technical criteria and corresponding accounting items. (Koszel, 2025) (Redondo Alamillos & De Mariz, 2022)

Element	Generic ESG KPIs	Taxonomy KPIs (Art. 8)
Level of analysis	The company as a whole	Individual economic activities
Object of measurement	Environmental, social, and governance performance, expressed through ratings, scores, or synthetic indicators	Share of eligible and/or aligned turnover, CapEx, and OpEx under the Taxonomy
Reference framework	GRI, ESRS, ESG ratings, MSCI indices	Regulation (EU) 2020/852 and delegated acts
Main function	Overall ESG assessment and support for risk/cost of capital estimation	Regulatory classification and guidance of financial flows
Required data basis	Broad set of heterogeneous ESG datapoints, often qualitative and quantitative	ESG base data filtered, standardized, and reclassified according to taxonomy criteria

Source: Binda B., 2026

The study by Garcia-Torea et al. highlights how the Taxonomy is perceived by banks as a strong source of uncertainty. This depends on the lack of clarity in translating the rules into practice, uncertain deadlines (timeline) and the absence of guidelines on supervisory modes (oversight). It will therefore not be enough to know which ESG data are available. It

will be necessary to define the process through which they are transformed into Taxonomy KPIs. (Garcia-Torea et al., 2024)

Taxonomy tracking is part of a broader ecological framework of European regulations. Redondo Alamillos and de Mariz analyze the construction of an “*ESG toolkit*” by the EU. This includes the NFRD, SFDR, CSRD, the Taxonomy, the Green Deal and various integrated sustainability initiatives. It can be said that the framework has imposed European sustainability standards at a global level, generating a *Brussels Effect*. (Redondo Alamillos & De Mariz, 2022)

Koszel, on the other hand, shows how the Taxonomy acts as a unique classification tool supporting stakeholders in their assessment process. KPIs such as turnover, CapEx and OpEx act as a single yardstick to measure the ecological transition of undertakings. (Koszel, 2025)

The CSRD strengthens and extends financial reporting obligations, requiring a larger volume of information. The SFDR obliges instead financial markets to report the sustainability of their products, requiring comparable and traceable ESG data. Hummel and Bauernhofer underline that the Taxonomy is the latest European regulatory innovation introducing an innovative approach to sustainability. (Hummel & Bauernhofer, 2024; Koszel, 2025; Redondo Alamillos & De Mariz, 2022)

Taxonomy tracking imposes a regulatory standardization that eliminates free interpretation through specific requirements and criteria. However, it increases the complexity of information collection, classification and integration. This happens especially for undertakings with diversified business models and long supply chains. (Garcia-Torea et al., 2024; Hummel & Bauernhofer, 2024; Koszel, 2025) (Visalli et al., 2023)

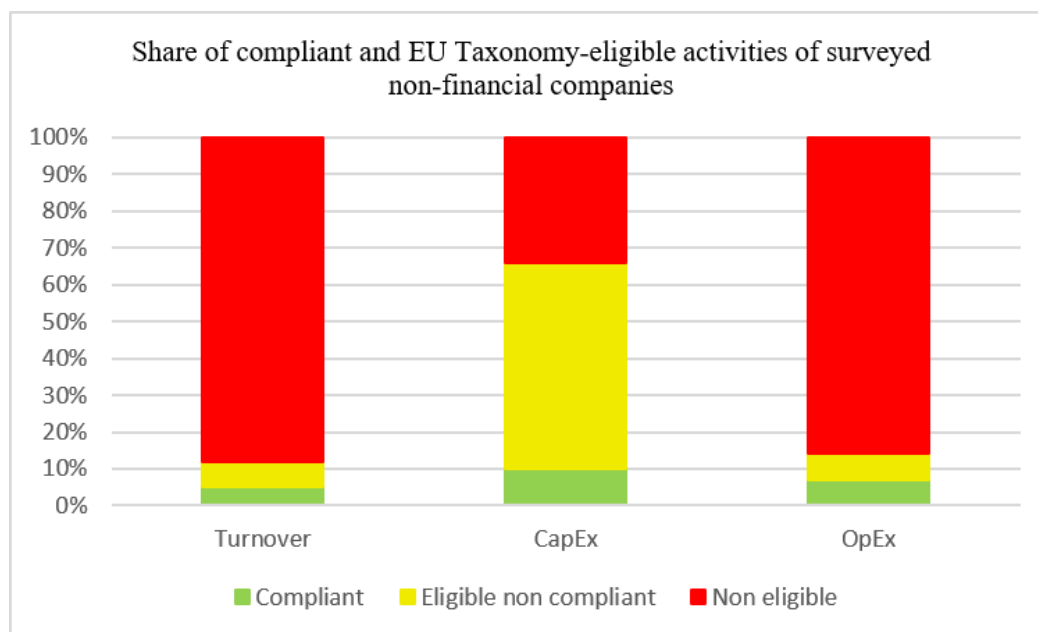
Regulation/standard	Main purpose	Type of data required	Role in taxonomy tracking
NFRD / CSRD	Corporate sustainability reporting	Broad set of ESG datapoints, structured according to ESRS	Provides the structured ESG data base
SFDR	Sustainability disclosure for financial products	PAI indicators and taxonomy-alignment information	Uses taxonomy KPIs to assess products and portfolios
Taxonomy	Classification of environmentally sustainable economic activities	Data on economic activities, turnover/CapEx/OpEx KPIs	Converts ESG data into regulatory taxonomy KPIs

Source: Binda B., 2026

The ESG database, unlike the taxonomy one, is fragmented, unstructured and dependent on external providers. ESG information is spread among *primary sources* (corporate websites, financial statements, sustainability reports, social media, news) and *secondary sources* (vendors that collect, organize and analyze ESG traits). According to Visalli et al, both present limitations. Primary data are contained in unstructured texts, while external agencies are slow and provide manually processed and limited data. Consequently, the absence of standardization on the ESG side, the different national formats and the heterogeneity of information presentation prevent the creation of common indicators, with the resulting impossibility of comparing undertakings. (Visalli et al., 2023)

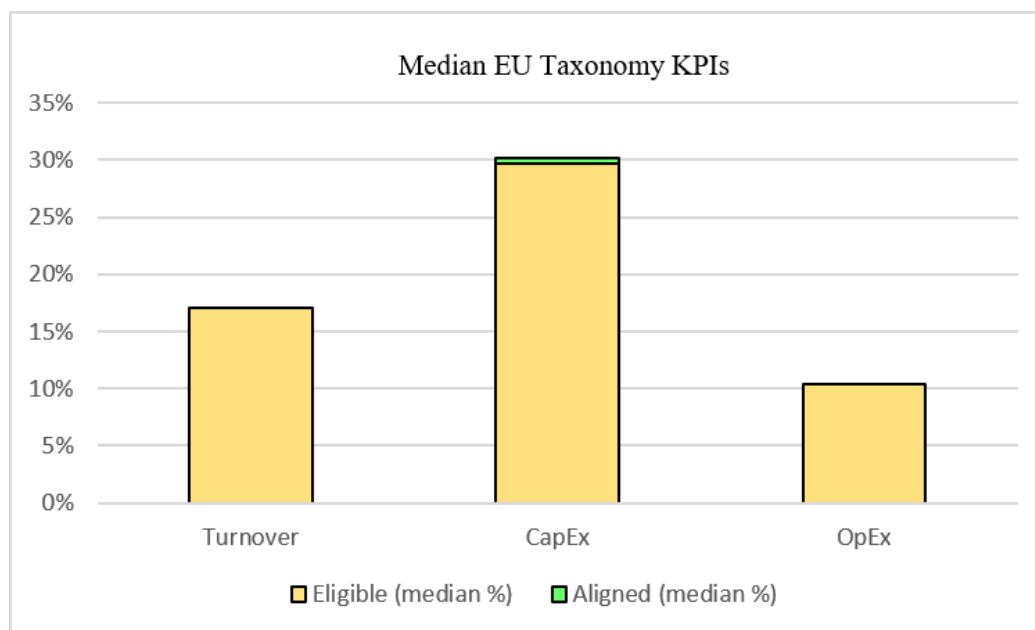
Koszel highlights the same problem, but at the regulatory level. Regulations and directives change so quickly as to oblige undertakings to continuously update their information systems and internal processes. The risk of not keeping pace translates into partial compliance and lack of alignment with the Taxonomy. The empirical analysis on a sample of listed companies on the Warsaw Stock Exchange shows that only little reported information complies with European guidelines. There is insufficient

organizational readiness on the part of undertakings. These do not yet have the internal structure or the competencies suitable for information collection. Limitations are present especially in the two key steps of reporting: the identification of eligible activities and the verification of their compliance. (Koszel, 2025)



Source: Binda B, 2026, based on Koszel (2025)

Schmoll et al. took the full reports of 190 large European undertakings, drafted according to taxonomy rules. A very evident gap was found between the *eligibility* and *alignment* steps. The data show high eligibility in investments (CapEx), of approximately 30%, which indicates that part of the activities are present in the Taxonomy list. At the time of the second verification, namely that of alignment, it is found that these activities do not respect all ecological criteria (DNSH and social safeguards). On average, aligned Turnover (revenues) and OpEx (operating expenditures) are on average equal to zero, while aligned CapEx is below 1%. In short, many undertakings carry out green activities, but almost none manages to demonstrate alignment through data. This is due to the fact that the software in the hands of undertakings fails to collect the details needed to demonstrate it. (Schmoll & Jatowt, 2025)



Source: Binda B., based on Schmoll et al. (2025)

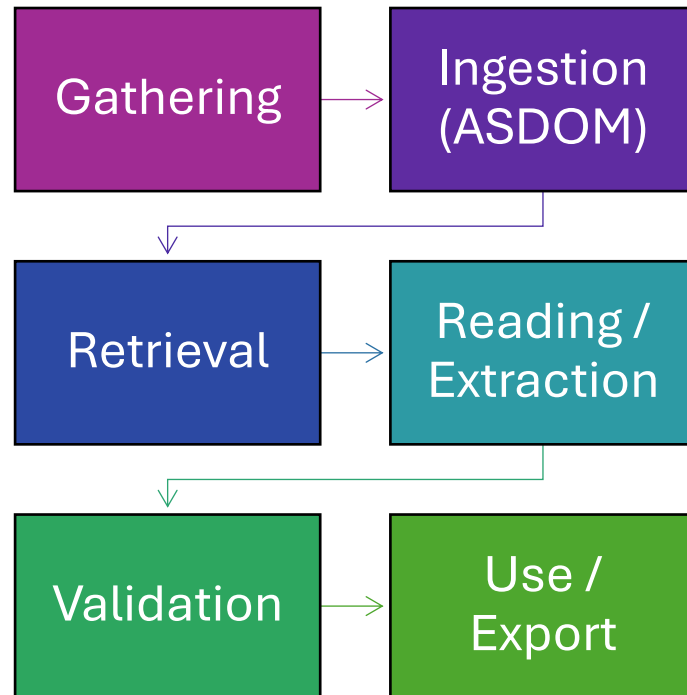
The result is that it is not enough to have ESG information at hand, but it is necessary to transform it into reliable indicators. It is necessary to prevent the complexity of regulations, the various sources and provider delays from creating inconsistencies between public reports, commercial databases and the calculation of KPIs. (Garcia-Torea et al., 2024; Hummel & Bauernhofer, 2024; Visalli et al., 2023)

In light of what has emerged, data collection is no longer an optional process or a description made superficially, but is a rigid procedure. The credibility of the KPIs presented before the company's stakeholders will depend on this information flow. Recalling Hummel and Bauernhofer, they observed that many undertakings show an “*endeavour to comply*” towards the Taxonomy. Garcia-Torea et al. show that the Regulation at the banking system level, in addition to requiring the calculation of the *Green Asset Ratio (GAR)*, creates regulatory uncertainty that leads banks themselves to costly internal reorganizations to adapt information systems to new mandates. (Garcia-Torea et al., 2024; Hummel & Bauernhofer, 2024)

Visalli et al. propose their vision on the use of AI-based platforms. Given that information is scattered everywhere and in different formats, the solution is the use of *Intelligent Document Processing (IDP)*. Instead of manually entering data into the software, an *end-to-end workflow* is created. It handles collection, ingestion and indexing, extraction and profiling. (Visalli et al., 2023)

Schmoll et al. also offer an opinion on Artificial Intelligence models. LLM models (*Large Language Models*) are not yet capable of reliably managing the end-to-end compliance process. They are instead useful as assistance tools to speed up the research (discovery) and data classification phase. They support experts by serving as a bridge (bridging) between legal definitions and unstructured texts. (Schmoll & Jatowt, 2025)

The dynamic that emerges is therefore that ESG data are no longer an aesthetic frame but are a fundamental infrastructure for the company. To be valid and usable, these data must follow a precise path along the corporate chain. They must be collected, standardized, made capable of communicating with different software and tracked step by step. Only in this way will the large volume of corporate documents be transformed into eligible and aligned KPIs.



Source: Binda B., 2026

3.4.3 Supply chain data and complexity of the manufacturing sector

When entering the manufacturing sector, collecting data within the company walls is no longer sufficient. It will be necessary to start collecting them outside the corporate perimeter, given that the majority of pollution, consumption and social impacts originate from long manufacturing supply chains. In order to calculate the environmental impact, the undertaking will have to retrieve data from all members of the network and share them along the entire network so as to make consistent decisions. This is fundamental for compliance with *sustainable supply chain management (SSCM)*, which will have to integrate economic, environmental and social objectives (the Triple Bottom Line perspective). (Mageto, 2021)

Mageto in his study demonstrates that new information technologies, in particular big data analytics, manage to provide insights that allow for identifying the weak link (the activities) that goes against sustainability, so as to be able to make corrective interventions. Tracking involves the reconstruction of a digital map of the entire supply chain; a dangerous

piece is represented by logistic emissions from transport channels that can significantly influence the ecological result. Sustainable supply chain management (SSCM) cannot occur without data processing, analytics, reporting and integration capabilities. (Mageto, 2021)

One therefore moves from abstract reporting to operational monitoring of the quantity of resources, raw materials and energy used along the manufacturing network. In this way, a company will have the necessary foundations to satisfy the requirements of the European Taxonomy.

Long and branched supply chains often create problems. With increasing globalization, supply chains have become increasingly complex. This type of global, branched and multi-tier structures (from Tier 1 to sub-suppliers of extractive raw materials) are the main characteristic of manufacturing companies. According to Akinola et al., due to these characteristics, data passes through various different actors and geographical areas “*degrading*”, creating bottlenecks and inaccuracies in the calculation of Scope 3 metrics. Quality and consistency, comparability, auditability and verifiability of the data will be lost. *Tier 1* companies have greater traceability thanks to advanced software. Suppliers located upstream (*Tier 2*, *Tier 3* or *Tier 4*), on the other hand, record data manually or do not have reporting knowledge. (Akinola et al., 2025)

Mageto emphasizes that structural complexity makes tracking the behavior of each actor difficult, especially in developing regions with few regulations. It is precisely in these contexts that, due to almost non-existent controls, issues such as child or forced labor arise. All these asymmetries undermine the reliability of taxonomy reports, leading to possible overestimations, omissions or errors. (Mageto, 2021)

Supply Chain Tier	ESG Data Maturity & Infrastructure	Taxonomy Disclosure Risks
Tier 1 (Direct Suppliers)	High ; digital traceability systems and integrated data flows.	Marginal methodological misalignment.
Tier 2 & Tier 3 (Sub-suppliers)	Medium-Low ; prevalence of manual records and information asymmetries.	Data fragmentation, reliance on imprecise macroeconomic estimates.
Tier 4 (Raw Materials / Extraction)	Very Low or Absent ; total opacity and lack of reporting standards.	Violations of Minimum Social Safeguards, calculation errors in Scope 3 impacts.

Source: Binda B., 2026

According to recent research by Akinola et al., the analysis of 240 ESG reports leads to a specific result. The weak point of *multi-tier supply chains* lies precisely in the *Tier 3* and *Tier 4* levels, where greater inconsistencies are found. To remedy this opacity, it is proposed to stop using spreadsheets for each supplier and creating information silos. In this way, the data problem improves significantly. The solution lies in graph-based models. These lead to an improvement of approximately 32% in the verifiability of ESG metrics. In 94.7% of cases it is possible to track the exact origin of the data, compared to 79.2% with old methods, reducing false positives. (Akinola et al., 2025).

Also in this debate, in order to eliminate information silos, Kadiyala aligns with Mageto. The author proposes to integrate ESG metrics within ERP systems. Also for Kadiyala, moving from a manual compilation of

spreadsheets to a manual and real-time collection guarantees accuracy and reliability in reporting. In this case, the company connects its ERP to sensor networks, industrial IoT devices (located in production plants) and its suppliers' platforms. All data will converge into a single database, considered the single source of truth. Consequently, sustainable metrics will have the same precision as traditional financial data. (Kadiyala, 2025)

Kadiyala and Mageto converge in stating that this integration leads to superior strategic functions such as scenario planning. It will be possible to simulate the various impacts of corporate decisions before actual implementation.

Recent literature also addresses the role of Artificial Intelligence (AI) and software that manage large amounts of unstructured data typical of the manufacturing sector. As previously mentioned, Hąbek analyzes various software, highlighting how AI can help reduce human workload. Machine learning models perform *anomaly detection*. This process flags outliers, missing or inconsistent records. Furthermore, the systems can develop predictive analytics and sectoral cluster groupings in order to allow managers to understand where to act immediately. (Hąbek, 2025)

However, both Hąbek and Kadiyala set a boundary. They warn that AI integrated into systems is still an application limitation in most of the manufacturing sector. This must be considered only as a support tool and not as a substitute for upstream data governance. If data are incomplete, wrong or falsified, AI will limit itself to analyzing them without correcting them. (Kadiyala, 2025) (Hąbek, 2025)

This debate finds confirmation in the investigation by Hummel and Bauernhofer on the reports of large undertakings, where they discover that there is a large gap between formal compliance and information quality. All undertakings publish the KPIs required by the Taxonomy (Art. 8), but

only 63% offer detailed descriptions of collection and calculation methods. The cause is immature internal information systems. In parallel, Håbek emphasizes strong pressure from ESRS standards (environmental domains: E1 on climate, E2 on pollution and E5 on circular economy, but also social ones: S1 on the workforce) which require detailed data along the entire chain. (Håbek, 2025; Hummel & Bauernhofer, 2024)

The scientific dialogue converges on one idea. Without a robust digital architecture and strong organizational capacity, the multi-tier supply chain is the main bottleneck of taxonomy disclosure. Consequently, the data will not be traceable and will not pass audit checks.

The implementation of the Taxonomy inevitably leads to *costs*. The development of new information infrastructures requires internal skills and new coordination between functions. These investments, however, will have to be offset by *benefits*.

3.5 The EU Taxonomy between compliance and value creation

Recent literature demonstrates how the joint introduction of CSRD, ESRS and EU Taxonomy represents the need to change undertakings from within. These changes simultaneously generate burdens in the short term but also potential benefits in the long term. (De Groen et al., 2022) (Department for Business and Trade, 2024)

The examined studies in fact converge on the idea that the Taxonomy is part of a broad sustainability reporting process.

3.5.1 The organizational impact of the European reporting framework

Before the introduction of the new rules, ESG disclosures were communicated on a voluntary basis. As there were no standards, the reporting models used were heterogeneous. They provided different and non-comparable levels of detail across undertakings and sectors. In this context, the European Sustainability Reporting Standards (ESRS) provide

a common language offering content, metrics and requirements that undertakings must respect to comply with the CSRD. At the same time, the criteria for assessing the sustainability of economic activities are introduced by the EU Taxonomy. It imposes the measurement of the share of operating expenditures, capital expenditures and turnover aligned with the requirements of Substantial Contribution, DNSH and minimum safeguards. (De Groen et al., 2022; Schütze & Sandbaek, 2025)

In the literature on Taxonomy Disclosure, the objective of the Taxonomy transpires: to increase transparency, reduce greenwashing and direct capital towards sustainable activities. On the practical side, market effects are still weak given that the system is in a consolidation phase.

The new regulatory framework goes beyond the need for a good communication approach. Sustainability is no longer an isolated element; it must be integrated within information systems and daily control processes. (Schütze & Sandbaek, 2025)

CEPS and Milieu conducted a cost-benefit analysis for EFRAG. It is shown that for undertakings, adapting to the first set of ESRS was not just a mere “*administrative cost*”, but also required recurring organizational investments. The authors estimated *incremental costs* of approximately €320,000 per year that a medium-sized undertaking, subject to NFRD and subsequently to CSRD, must bear for the preparation of reports in line with the ESRS. This figure is divided into *internal personnel costs* (salary of more than two full-time people, FTE) and *external expenses* (approximately €146,000). To this are added approximately €287,000 of *one-off costs* to be borne in the first year to achieve compliance. (De Groen et al., 2022)

Overall, it is demonstrated that in order to adapt to the new regulatory framework, costs are not borne solely for drafting reports. Structural

investments intended to change the company's way of operating in the long term are necessary.

As regards total expenditure at European level, the undertakings involved spend approximately €1.7 billion in *one-off costs* and €1.9 billion in *recurring costs*. However, these costs do not affect all undertakings in the same way. They vary based on company size, level of organization and prior maturity of reporting systems.

Approximately 25% of recurring costs is attributable to information produced and used also by other sustainable finance regulations (SFDR and CRR). (De Groen et al., 2022)

The study also maps *direct costs* (administrative and assurance) and *indirect costs* linked to supply chain, competitiveness and litigation. The largest weight is represented by *assurance*. At the aggregate level, data verification is divided into two levels. *Limited assurance* requires expenditure varying between €2.6 and €3.9 billion per year. The figure is much higher for *reasonable assurance*, between €6 and €9.7 billion per year.

In practice, on an organizational level, are required investments in information systems, data collection along the supply chain, staff training, revision of internal procedures and strengthening of governance. (De Groen et al., 2022)

The EU Taxonomy adds a further level of complexity to this framework. The British Department for Business and Trade reconstructed, through a survey, the “*compliance journey*” to the Taxonomy, identifying its main cost drivers and the difficulties encountered by reporting corporates.

As regards data collection systems, two levels of expenditure are shown. In the short term, a few hundred thousand euros are invested for an *Upgrade* of existing software. For a complete *Overhaul* of ERP systems, on the other hand, we speak of millions of euros or tens of millions if

multinational groups are involved. (Department for Business and Trade, 2024)

On the consultancy side, specialized services are among the most expensive for many undertakings. For the first year of Taxonomy reporting, figures hover around €50,000 and €100,000 for medium-large undertakings. For complex groups, figures range from hundreds of thousands to a million. (Department for Business and Trade, 2024)

Due to the novelty and complexity of technical criteria, many undertakings find themselves forced to introduce dedicated teams or seek help from external consultants to interpret regulatory requirements or map activities. These costs will tend to be present until the stabilization of the regulatory framework. (Department for Business and Trade, 2024)

The studies, therefore, agree that part of the costs are transitional. These are linked to the adaptation phase rather than to the ordinary functioning of the reporting system.

It is therefore also confirmed by the literature on Taxonomy disclosure that implementation, at least in the initial phases, requires employee training, but also the search for historical data on the environmental impact of counterparties. In addition to this is added the adjustment of reporting processes and IT systems. All this leads to high costs in the first years of application. (Schütze & Sandbaek, 2025)

Empirical literature highlights DNSH screening as the most complex phase of alignment. There are two major problems. A first obstacle is linked to the absence of standardized metrics and historical data to demonstrate compliance with the requirement. The real stumbling block, however, is multinationals operating also in non-EU countries, where reference European directives do not exist (e.g. *REACH Regulation* or *Water Framework Directive*). Consequently, to try to demonstrate

compliance with equivalent criteria, resort is made to expensive external consultants. (Department for Business and Trade, 2024; Schütze & Sandbaek, 2025)

3.5.2 The EU Taxonomy as a potential driver of value

Since Regulation (EU) 2020/852 is recently introduced, the literature regarding the economic benefits for undertakings is still limited. However, several contributions identify taxonomic mechanisms that could transform into a strategic lever. These concern three dimensions: transparency, the integration of sustainability into decision-making processes and the development of new capabilities. (Department for Business and Trade, 2024; Schütze & Sandbaek, 2025)

On the transparency front, the legislator introduces the EU Taxonomy to create a shareable language, reduce the ambiguity linked to the word “*sustainability*” and the risk of *greenwashing*. Studies on disclosure on the one hand indicate that the Taxonomy improves the comparability of environmental information between competitors, but, on the other hand, benefits in terms of reputation and reduction of asymmetries are partial and influenced by regulatory uncertainty. This is due to the presence of many interpretative documents (FAQs) created by the authorities and to application discretion. (Schütze & Sandbaek, 2025)

For integration into decision-making processes, the EU Taxonomy obliges undertakings to connect their industrial plans to taxonomy KPIs. Undertakings will not be able to freely choose which actions or projects to undertake without respecting the environmental objectives of the EU, thus changing *Performance Management systems*. *Capital Allocation* is guided by decisions relating to CapEx. Management will direct investments towards decarbonization, energy transition and resource optimization because they guarantee greater economic sustainability and lower risk in the long term. (Schütze & Sandbaek, 2025)

The *British Department for Business and Trade* highlights that for many companies a synergy was found between financial departments and ESG ones. A close collaboration was therefore created to collect and interpret data for strategic purposes. From the interviews it emerges that the framework offers clear guidance for setting up transition plans (an example being undertakings in the hydrogen and renewable energy sector), so as to connect investments, KPIs and long-term objectives. (Department for Business and Trade, 2024)

On the whole, the literature suggests that the Taxonomy does not automatically improve a company's performance, but can modify investment evaluation criteria, moving from a financial logic to an integrated logic. This is important for capital-intensive sectors, where Taxonomy-aligned KPIs affect capital allocation, project selection and priorities. (Department for Business and Trade, 2024; Schütze & Sandbaek, 2025)

As regards the development of organizational capabilities, the strand concerning the costs-benefits of sustainable reporting highlights that the true value for the company does not reside in the document itself, but in the skills developed internally to process it. Rigorous ESRS standards and the Taxonomy stimulate the evolution of such capabilities through various levers. These include: the reinforcement of data infrastructures, construction of cross-functional teams, monitoring and transparent governance of the supply chain. But also the adoption of new internal policies and due diligence processes. (De Groen et al., 2022)

In this context, alignment with the Taxonomy becomes a factor of competitive advantage. Undertakings that know how to use data to manage processes and decisions transform the compliance obligation into an operational lever. (De Groen et al., 2022)

In summary, it can be stated that in manufacturing, Taxonomy, CSRD and ESRS show the relationship between costs and effort in collecting complex data (such as those on Scope 1, 2, 3, energy consumption, suppliers). However, costs are balanced by advantages: process efficiency, innovation, better access to financing. The real difference in manufacturing lies in managing to transform mere reporting into a tool that guides investments and production. (De Groen et al., 2022) (Department for Business and Trade, 2024)

This trade-off forms the backdrop for the analysis of business case studies such as that of the rubber/tyre sector. In these contexts, various pressures coexist, both from restrictions by European regulations and from those of markets requiring products and materials that are increasingly sustainable. The question therefore arises as to how these undertakings manage to translate this compliance into competitive advantage.

3.6 The Tyre & Rubber sector in the new European sustainability framework

The *rubber and tyre sector* is considered one of the manufacturing sectors with the highest energy consumption, emission production and intensive use of materials. It can therefore be considered an interesting case study in order to analyze how European sustainability policies impact these companies. (Sienkiewicz et al., 2017)

This case study is relevant because the analyzed studies do not deal directly with the EU Taxonomy (given that it is a recent regulation). What has already been found is that the tyre has an enormous impact on the environment (in terms of waste, emissions, long-term environmental risks) throughout its entire life cycle. (Mayer et al., 2024)

This sub-chapter will present a critical review of the scientific literature applied to the Tyre & Rubber sector. A useful theoretical bridge will

therefore be built to introduce and justify the subsequent corporate case study focused on Pirelli S.p.A.

3.6.1 The Tyre & Rubber sector as a context with high material and emission intensity

Sienkiewicz et al. and Mayer et al. identify the tyre sector as a major user of materials and energy.

Sienkiewicz's review describes that the tyre has a high compositional complexity. Vulcanized rubber counts for roughly 70 to 80 percent of the total mass. This elastomer blend (natural and synthetic) to achieve its properties, is filled with carbon black and silica. (Sienkiewicz et al., 2017)

Mayer instead highlights the issue related to waste. Annually, approximately 3 billion tyres are produced, of which approximately 800 million become waste. A projection is made according to which, by 2030, this waste will rise to 5 billion. (Mayer et al., 2024)

The same author proposes an estimate of the production intensity of a tyre. It takes approximately 6 MJ of electrical energy, 45 liters of water, 0.02 kg of solvents. On the waste side, approximately 0.5 kg of solid waste, 243 g of particulate matter emitted into the atmosphere, NH₄ and suspended solids in water are produced. On a global scale, this determines direct effects on climate objectives and sustainable practices. (Mayer et al., 2024)

In this framework, the Tyre & Rubber sector represents a paradigmatic case. Climate mitigation, efficient use of resources, pollution prevention and protection of the environment play a fundamental role in enabling alignment with climate objectives.

This evidence links to what was said in the previous paragraphs regarding the need to use advanced information systems. Interventions, therefore, to

modernize structures and plants fall under CapEx. In this case, the trade-off between costs and potential value creation emerges.

3.6.2 Global tyre supply chain, traceability and ESG data

The literature agrees in describing the tyre supply chain as complex and exposed to supply risks. Africa and Asia have suffered mass deforestation due to the need to cultivate natural rubber. Millions of hectares of high-biodiversity forests have been converted into Hevea plantations. The synthetic part is instead composed of *petrochemical feedstocks* and various chemicals mixed together. (Mayer et al., 2024)

Moving to a regulatory perspective, Trudsø divides the life cycle of the tyre into five phases: raw materials, production, use, End-of-Life Tyres (ELT), reuse. Each stage is subject to distinct regulations that goes from waste, atmospheric emissions, water, moving to REACH and directives on end-of-life vehicles. All this complicates the uniform assessment of risks along the supply chain. (Trudsø et al., 2022)

During the use phase, wear particulate matter (Tire Wear Particles, TWPs) is generated. During its life a tyre loses between 10 and 17% of its mass. It then will be dispersed into the environment in the form of particles. The per capita impact varies from a few tenths to over 5 kg per year. This pollution depends on driving habits, context and kilometers driven.

This particulate matter is dispersed on roads, waterways, atmosphere, and mixed with other materials. This complicates traceability and the construction of ESG indicators comparable over time and space. (Trudsø et al., 2022)

On the corporate front, Sava shows how increasing importance is given, among major tyre manufacturers, to emissions along the value chain (Scope 3). On the one hand, efforts are made to commit to net-zero and due diligence projects related to natural rubber; on the other hand,

disclosure on Scope 3 is fragmented and difficult to compare. From this it transpires that the measurement of impacts along the supply chain is still in the process of being structured. (Sava et al., 2025)

These critical issues find consistency with what was previously explained: the lack of ESG data from third-party suppliers (often SMEs or smallholders in emerging countries) forces the companies leading the supply chain to use estimates or proxies. Consequently, this compromises the quality and verifiability of the information. On the cost side, guaranteeing traceability mandates the use of advanced auditing and advanced frameworks (Pirelli, for example, uses the *TNFD LEAP* protocol to map deforestation risks in Sumatra). This increases administrative and information costs significantly.

3.6.3 Circular economy of tyres: between recovery and new externalities

The European Commission, through Delegated Regulation (EU) 2023/2485, clarified that the manufacture of tyres falls among the eligible economic activities for taxonomy alignment. These are found within category 3.6 (“Manufacture of other low-carbon technologies”) due to the potential in reducing greenhouse gas emissions in the road transport sector.

The management of End-of-Life Tyres (ELT) and the use of circular models within the sector are among the most recurrent topics in the literature.

Sienkiewicz shows that the EU, USA and Japan have launched an entire industry based on ELT. Recovery rates revolve around 95%, which is divided into *energy recovery* and *material recycling*. (Sienkiewicz et al., 2017)

Trudsø confirms the presence of three ELT management models in the EU: Extended Producer Responsibility, free market and tax system. He quantifies that in Europe end-of-life tyres reach approximately 3.2 million

tonnes each year. The choice regarding their destination (energy recovery or material recycling) varies from one EU country to another. (Trudsø et al., 2022)

Mayer criticizes the circular economy solutions (for example, the use of rubber granulate for flooring) adopted so far. Although they bring various benefits, they are not zero-impact. The chemical components and metals present in the new products derived from recycling do not disappear. Due to weather and rainfall, toxic substances are released into the soil and groundwater (leaching phenomenon). Fundamentally, recycling solves the problem related to the volume of waste, but on the other hand, it creates new problems, namely new pollutants. Often, these latter, along with environmental risks, are still poorly quantified. (Mayer et al., 2024)

A company must therefore know how to measure and manage this trade-off with more precise analyses (what the EU Taxonomy requires with the DNSH criteria).

Sava, in his study, offers a synthesis of various corporate reports and international bodies. He found that although advanced recycling techniques already exist in some countries, the global recycling rate of ELTs revolves around 30%. However, a large portion remains unaddressed. In some areas of the world, these ELTs still end up in landfills. (Sava et al., 2025)

3.6.4 Material and process innovation in the tyre sector

Among the material-related innovations, the use of alternative raw materials stands out. These include silica derived from rice husks, latex extracted from dandelions, or the use of soybean oil as a replacement for petroleum-based extender oils. (Sava et al., 2025)

On the digital front, Pirelli presents the *Cyber™ Tyre*, while Michelin presents the *VISION concept tyre*. The two companies integrate sensors

for monitoring pressure and wear rate in order to improve fuel consumption and particle dispersion. (Sava et al., 2025)

However, Sava tends to point out that these technologies carry economic barriers. The use of bio-based or recycled materials leads to a cost 2 to 3 times higher than that of fossil-based materials. (Sava et al., 2025)

From the performance management perspective, technological innovation in the sector complicates the construction of KPIs. Measuring the percentage of sustainable materials, TWP reductions, progress in recycling, and across the entire life cycle requires new technical and environmental indicators. (Mayer et al., 2024; Sava et al., 2025; Sienkiewicz et al., 2017)

Complying with environmental regulations requires significant investments in R&D. Firms selling premium tyres, such as Pirelli and Michelin, have customers who are willing to pay higher prices. As a result, these companies pass R&D costs on to the final selling price. Conversely, those selling in the mass market, such as Goodyear and Continental, have price-sensitive customers. These companies must absorb these additional R&D costs, eroding their own margins.

3.6.5 The sector's response to the European regulatory framework: towards the Pirelli case

The combination of CSRD and EU Taxonomy requires a restructuring of internal governance and corporate Performance Management. *Double Materiality* reporting obliges the integration of financial and operational information systems. (Sienkiewicz et al., 2017)

The frontrunners (Pirelli and Michelin) do not limit themselves to simple compliance with regulations, but approach them proactively. They use double materiality and advanced frameworks for nature- and biodiversity-related risks (such as TNFD LEAP). The literature also highlights the

introduction of sustainable finance instruments, such as Pirelli's €600 million Sustainability-Linked Bond, tied to decarbonization targets. (Mayer et al., 2024; Sava et al., 2025)

Actors oriented toward mere compliance, such as Bridgestone, Continental, and Goodyear, have a different approach. They only report data on direct emissions (Scope 1) and those from purchased energy (Scope 2). (Mayer et al., 2024; Sava et al., 2025)

Also, misalignments between product-related regulations and sustainable reporting frameworks have been found. Individual chemical substances used in the production phase are controlled by long-standing regulations such as REACH or the IED directive. These do not control the mixture effect of chemical substances nor the toxic substances formed through wear. The lack of coverage of these aspects makes it difficult to demonstrate alignment with the DNSH (Do No Significant Harm) criterion. (Trudsø et al., 2022)

This evidence indicates that enterprises are trying to adapt to the new European regulatory framework. Compliance requires new governance processes, significant investments in both plants and data collection infrastructure, and the integration of financial and environmental variables.

3.7 Original contribution of the thesis and research questions

From the analysis of the state of the art conducted in the previous sections, it can be gathered that the *Tyre & Rubber* sector is situated in a rather complex regulatory context and represents a market in continuous growth regarding sustainability. Translating practices into reporting aligned with CSRD, ESRS, and the EU Taxonomy is a field that is still evolving and under-explored by scientific literature.

Precisely this, the lack of studies linking the EU Taxonomy to companies in the rubber sector such as Pirelli S.p.A., constitutes a research gap (*literature gap*) that remains to be filled.

Despite the theoretical foundation, the examined literature presents at least three relevant limitations with respect to the objectives of this thesis:

1. Studies conducted on the European sustainability framework focus predominantly on *macro* analyses (regulatory, sectoral, market). Little attention is paid to the application of the EU Taxonomy at a *micro-organizational* level. This level encompasses how undertakings build their methodology, KPIs, cross-functional involvement, and the use of information systems to report *CapEx*, *OpEx*, and *Turnover*.
2. Literature describes LCA analysis methodologies, circular economy practices, and product innovations. What is missing in the literature is an understanding of how such elements are managed by corporate leadership and how undertakings balance compliance costs and long-term benefits (*trade-offs*).
3. A lack of concrete contributions regarding a non-financial undertaking operating in a material-intensive sector. Substantially, there is a need to understand the relationship between Taxonomy-CSR/ESRS-sustainability management practices within such an enterprise. Second, how taxonomy reporting is integrated into broader corporate processes.

In this sense, the Pirelli case – the subject of the following chapter – can be considered a specific example of the *Tyre & Rubber* sector. It will be demonstrated how this large multinational reacted to regulatory challenges, how it adapted, and the cost-benefit ratio it recorded.

The original contribution of this research is articulated on two complementary levels:

- Analysis of how a large manufacturing company in the tyre sector, such as Pirelli, implemented the European Taxonomy, integrating its systems and interpreting it not as a decorative or secondary activity, but as a commitment to guarantee its long-term competitiveness.
- The Pirelli case is used to explore the operational tensions generated by this regulatory framework. There is an increasing need to answer questions regarding transparency and accountability along the supply chain, the risk of competitive disadvantages compared to non-EU operators not subject to the same regulations, and the adaptation of general criteria to technically specific contexts.

In light of these elements, answers will be formulated to the following research questions:

RQ1 *How has the European Taxonomy been implemented by Pirelli (methodology, KPIs, relationship between functions, information systems)?*

RQ2 *What organisational, informational, and compliance challenges arise from the implementation of the EU Taxonomy, and how does management address them to create long-term value?*

CHAPTER 4

4.1 Research methodology and study design

To answer the research questions formulated in Chapter 3, this study adopts a qualitative approach. It is based on a single case study. In the literature, this methodology is considered the most suitable scientific tool to analyze a complex and contemporary phenomenon within a real-world context (Siggelkow, 2007; Yin, 2018). Through this case, the opportunity is provided to access the internal dynamics of a multinational manufacturing enterprise operating within a complex sector characterized by high material and process intensity.

The research is structured around the qualitative case of Pirelli & C. S.p.A, since it can be considered as a perfect example of a hard-to-abate manufacturing company that adapted itself to EU sustainability frameworks. The selection criteria are presented in Section 4.1.3.

The study of this case allows for an in-depth exploration of the micro-organizational level (how and why), partially filling the gap identified in the literature (which focuses on macro-regulatory, sectoral, and market analyses) (Alessi et al., 2024; Brabec & Macháč, 2026).

4.1.1 Data sources and materials

In this study, primary sources include interviews conducted with individuals belonging to the company Pirelli & C. S.p.A. The interviewees hold key roles in managing topics related to sustainability and non-financial reporting. Their contribution was therefore essential and qualified to provide detailed information on: EU Taxonomy implementation, involvement of corporate functions, information systems, integration with CSRD/ESRS, costs and trade-offs, supply chain management, and the use of sustainability as a competitive advantage.

Consequently, the interview transcripts represent in themselves the main material on which the analysis is conducted.

Secondary sources, on the other hand, include:

- Public documents from Pirelli, including the Pirelli Annual Reports from 2021 to 2025 and the Pirelli Industrial Plan.
- European regulatory documents, in particular Regulation (EU) 2020/852 on the Taxonomy, the delegated acts relating to the climate change mitigation and adaptation objectives, and the reference texts of the CSRD and ESRS.
- Any public sources referring to investors, communications on ESG topics by the company, and information on sustainability ratings and indices.

The combination of both sources allows for increasing the veracity of the emerging evidence.

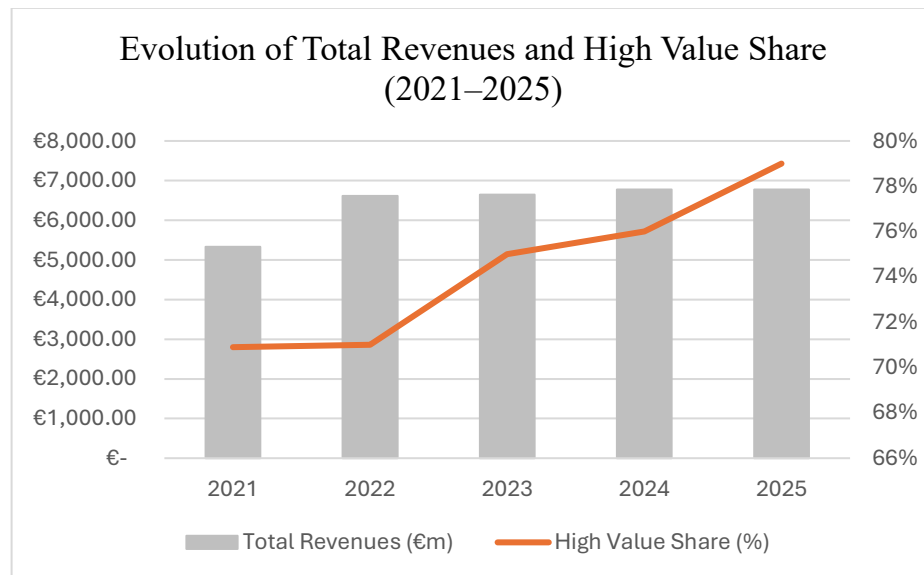
4.1.2 Data collection and analysis method

The interviews were outlined on the basis of the research questions and the themes that emerged from the literature review. Secondly, the documents listed above relevant to the research were selected and collected.

4.1.3 Rationale for the choice of the case study: Pirelli & C. S.p.A.

The adoption of a single case study with a focus on Pirelli & C. S.p.A. requires an explanation that helps to understand why this company represents emblematic evidence and not a sample of pure convenience. The company was identified as an exemplary case regarding the topic of the management and transposition of the new European sustainability frameworks.

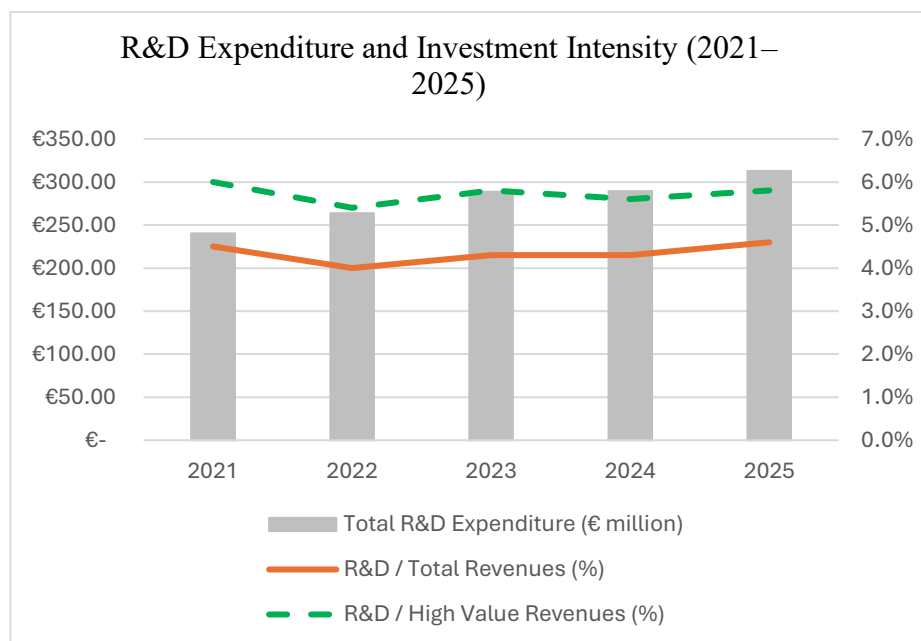
A first relevant point concerns the theme of *Industrial scale and strategic market positioning*. Pirelli positions itself among the leading global Tier 1 tyre manufacturers. Mainly, the segment in which the company operates is Pure Consumer (car, motorcycle, and cycling), also serving the High Value Segment. In the 2025 Annual Report, interesting data can be found regarding Revenues and adjusted EBIT margin. To the former is associated the figure of 6,776.2 million euros, to the latter a percentage of 16% (1,081.4 million euros). These data are among the highest in the tyre makers sector. Finally, the High Value segment alone represents 79% of total turnover. This indicates that the company does not aim to challenge its competitors on the price of standard products, but on knowing how to innovate and introduce advanced technology into its products. (Pirelli & C. S.p.A., 2024, 2025)



Source: Own elaboration of Pirelli Annual Reports 2021-2025

With regard to *R&D, Patents, and Technology*, Pirelli invests approximately 4.6% of total turnover in Research and Development, one of the highest shares within the entire Automotive & Parts sector. R&D expenditure by the company was approximately 312.7 million euros in 2025 (289.5 million € in 2024). (Pirelli & C. S.p.A., 2025)

At the technological level, the company has a portfolio of approximately 4,000 technical homologations and is the first company in the world to have introduced tyres equipped with sensors that transmit real-time information and V2X protocols. It is considered a strategic asset awarded at an international level by *AutoTech Breakthrough Awards 2025*, *Frost & Sullivan Company of the Year*, *AutoBest Safety Award*. (Pirelli & C. S.p.A., 2025)



Source: Own elaboration of Pirelli Annual Reports 2021-2025

At the level of *ESG recognitions and records of sustainability*, Pirelli is in the *Top 1% of the S&P Global Sustainability Yearbook* (2025 and 2026), presenting the highest score in the *Auto Components and Automotive category* (84 in 2024 and 86 in 2025). The company has also been included in CDP's Climate A List for 7 consecutive years. Other independent rating agencies also associate ratings of excellence with the company.

The Net Zero 2040 plan across the entire value chain was formalized with SBTi, also establishing intermediate targets for 2030. Talking about industrial records, the company was also the first in the world to produce

FSC (Forest Stewardship Council) certified tyres. (Pirelli & C. S.p.A., 2024, 2025)

Finally, concerning *Integration between sustainable finance and regulatory compliance*, the company was the first to issue a Sustainability-Linked Financing Framework and Bond. In terms of regulations, it ranks among the first Italian industrial manufacturing groups to have addressed the application of the CSRD/ESRS framework (Legislative Decree 125/2024) and Regulation (EU) 2020/852. (Pirelli & C. S.p.A., 2025)

Based on these data, Pirelli is not a convenience sample, but represents precisely an exemplary type of case study. The combination of the various themes makes the company a unique and ideal element to understand the mechanisms of transposition, integration, and management of European regulations relating to the topic of sustainability.

4.2 Company profile and overview: Pirelli & C. S.p.A.

4.2.1 Identity, history, and business model

Founded in Milan in 1872 by Giovanni Battista Pirelli, Pirelli S.p.A. is an Italian multinational enterprise specialized in the design, production and commercialization of tyres for cars, motorcycles and bicycles. The Group is listed on the stock exchange and has its registered office in Milan.

Born as a producer of vulcanized rubber articles, it has progressively shifted its core business toward the tyre sector, dedicating itself to the Consumer segment. It presents a turnover equal to approximately 6.8 billion euros (2025 data). (*Pirelli in breve*, n.d.; *Pneumatici Consumer*, n.d.; Pirelli S.p.A., n.d.)

The business model is formed on the orientation to the High Value segment (79% of group turnover in 2025), characterized by tyres above 18" with high technology (Run Flat™, Seal Inside™, PNCST™, Elect™, Cyber™,

Racing and Collezione) and performance destined for Prestige range cars (e.g. Ferrari, Lamborghini, Maserati, Aston Martin or Porsche) and Premium (e.g. Audi, BMW, Mercedes, Land Rover). The company also operates in the Cycling world with the main cycling teams of the UCI category. (*OEM Partnerships*, n.d.)

The distinctive element of Pirelli's strategy is the approach to Co-Design with the main vehicle manufacturers (Original Equipment Manufacturers – OEM). Through these collaborations, the company develops “custom-made” tyres (Perfect Fit). This positioning leads to a double competitive advantage:

1. *Loyalty of the Replacement channel*: the motorist will tend to repurchase the same original equipment homologated tyre. This in order to keep performance and safety unaltered. (*OEM Partnerships*, n.d.)
2. *Margin resilience*: the High Value segment is not as sensitive to the swings of the economic cycle and to price competition, compared to the mass-market segment. Operating margins will therefore be stable and high. (*Pirelli in breve*, n.d.)

4.2.2 Industrial footprint, global presence, and human capital

The company has a balanced global presence to minimize geopolitical and logistical risks, serving the markets with the highest growth rate. (Pirelli S.p.A., n.d.)

The countries in which the company operates are over 160 with over 20,000 specialized points of sale and partners at a global level. The group has at its disposal 18 industrial plants located in 12 countries. In Europe they are located in Italy, Germany, the United Kingdom and Romania, in the rest of the world instead they are found between Brazil, Mexico, Argentina and the United States; in the East finally they are present in

China, Russia, Indonesia and Turkey. This enormous presence combines the proximity of OEM customers' production sites with the optimization of transport and production costs (local-for-local strategy). (*Pirelli in breve*, n.d.)

Pirelli's workforce is composed of 29,680 people. The high specialization of the latter represents an extremely important asset. The company, in fact, offers continuous training programs, workplace safety and development of new skills. (*Pirelli in breve*, n.d.)

In line with Industry 4.0, Pirelli has implemented advanced automation systems, IoT sensors and process data analysis (Total Efficiency 4.0). Substantially it is possible to track energy consumption, the reduction of vulcanization scrap and predictive maintenance of plants in real time. (*Total Efficiency 4.0*, n.d.)

4.2.3 R&D, patents, and digitalization

Research and Development constitutes the true beating heart of Pirelli's strategy. To this section a constant share equal to approximately 5.6% of revenues from High Value sales is dedicated.

The company presents 12 regional R&D centers located in key markets, with approximately 2,000 engineers, chemists and researchers constantly committed to the development of new compounds, structures and production processes. (*Ricerca & Sviluppo*, n.d.)

In addition to the product portfolio, Pirelli also presents a large portfolio of patents (over 6,000) filed at a worldwide level. The company does this in order to protect its inventions regarding materials, structures and tread of the tyre or innovative technologies. (*Ricerca & Sviluppo*, n.d.)

Among the technological innovations are Virtual Co-Design and the use of artificial intelligence algorithms, solutions that accelerate time-to-

market. In addition to this there is the ELECT technology. Tyres equipped with this wording are mounted on electric and plug-in hybrid vehicles, they guarantee low Rolling Resistance for a better duration of the batteries. They also have a reinforced structure that can support the weight of the latter. Pirelli is also mother of the Cyber Tyre™ (illustrated previously) and also deals with the engineering of sustainable materials. (*Ricerca & Sviluppo*, n.d.)

4.2.4 Motorsport and racing as a technology laboratory

Competitions represent a fundamental field for the company, which in fact is active in over 350 world car and motorcycle motorsport competitions. (*Racing*, n.d.)

Since 2011, Pirelli holds the role of Global Tyre Partner and exclusive supplier of the FIA Formula 1 World Championship. Motorsport is for Pirelli an open-air laboratory (from track to road). The conditions of the tracks allow for rapidly testing new compounds, structures, simulations in such a way as to transfer the acquired knowledge into daily road products. (*Racing*, n.d.)

On the basis of all this information, Pirelli positions itself as an emblematic case study to examine the impacts of European regulation.

4.3 Empirical findings: Pirelli and the EU Regulations

4.3.1 The strategic vision of sustainability in Pirelli

According to Pirelli, in order to be sustainable, sustainability must bring value to stakeholders and to the company.

For Pirelli, sustainability means enduring in the long term from a competitive perspective. To do this, the company approaches all elements connected to sustainability (which are essentially characterising elements of the business) from a strategic standpoint. Everything the company does

must have a correlation with value creation, which must always and in any case be for the company as well as specific for stakeholders.

In the case of materials, the objective of increasing renewable rather than recycled materials within the tyre has strong business drivers. These range from the demands of original equipment customers to the prevention and mitigation of risks arising from regulations that will enter the market in the future.

In the case of the product relating to customers, Pirelli has a highly technological, innovative, and highly anticipatory approach: precisely due to the direct relationship with Original Equipment Manufacturers (OEMs), the company sees developments well before they arrive on the market. By working together with car makers, for example, on the design of tyres that will be released in several years, Pirelli will be able to maintain an anticipatory capability regarding sustainability trends, material demand, and future regulations.

The company, therefore, must set objectives of this kind. These will entail costs, but in order to remain one step ahead of competitors, it must know how to manage them. This is the economic penalty that the “first mover” must bear. The earlier new materials must be introduced into the product, the lower the supply and demand on the market will be, and consequently, the costs will be much higher. Being new and niche raw materials, specialized suppliers will be limited on the supply side. On the demand side, manufacturers operating primarily in the mass market are not yet willing to offer these premium products. The company, however, has an anticipatory obligation compared to its peers (competitors).

Given that Pirelli is positioned in a High Value market, all elements are interconnected; it is necessary to have a defined integrated strategy (from

an environmental, technological, economic, and commercial perspective), oriented toward value creation for the company.

The macro-concept (the objective) is to mitigate risks and seize opportunities arising from this regulatory context. Naturally, high-level managerial skills are required, because Pirelli must mitigate threats as much as possible and maximize benefits, otherwise one easily risks incurring undesired costs. The company looks ahead to 2030–2040 and formulates its strategies to mitigate risks and seize opportunities. This is the strategic model the company employs.

The other pillar of the strategy is the managerial attitude regarding the fact that choices increasingly depend on the expectations of stakeholders. Here, the strategic dimension lies in knowing how to manage stakeholder expectations considering that the company operates with a scarce economic resource. It is necessary to understand how to satisfy the various stakeholder expectations in a balanced manner, even when non-converging. The issue is therefore that the stakeholder actually has the capacity to impact the business positively or negatively, but 100% satisfaction of a single stakeholder is unsustainable for the company, as it would lead to long-term problems. The ability to balance the partial satisfaction of all stakeholders is an art, but it enables the company to remain solid in the long term.

Looking at Pirelli's Sustainability Plan, one can see the company's commitment across various pillars (Planet, People, Customer/OEM, Suppliers, Shareholders/Investors, Local Community) in order to satisfy all stakeholders. It will then be Pirelli itself that calibrates the type of engagement by maximizing its effectiveness, without becoming lost in abstract analyses or philosophies.

In the supply chain due diligence process, the company maps supply chain risks according to their severity (risk materiality), subsequently scaling investments in audits and corrective actions proportionally (pro-rata) to the identified level of risk.

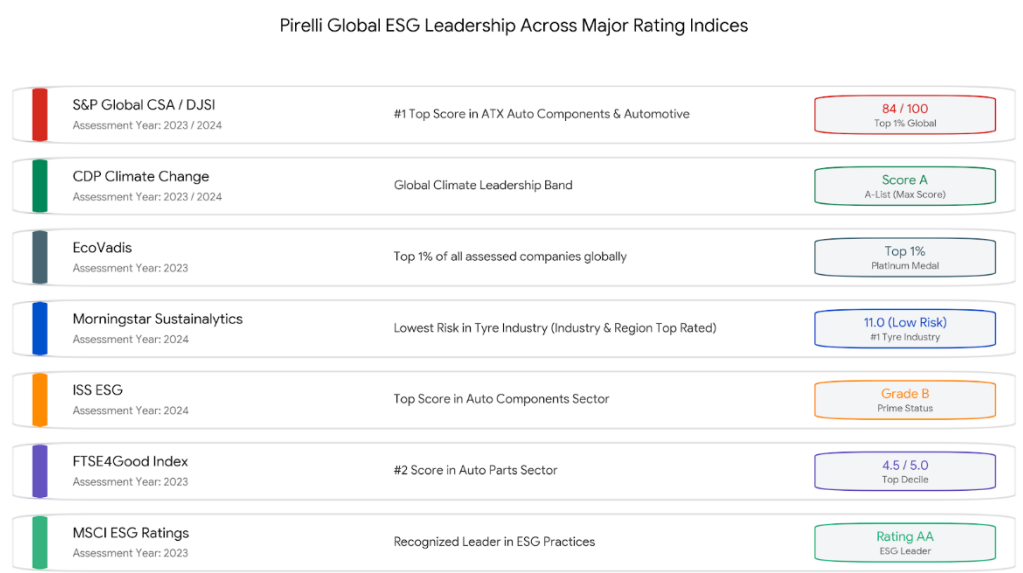
Another fundamental element from a strategic perspective is materiality: namely the relevance of a topic or a decision, without which no progress can be made. Materiality can be described as the capacity to impact specific stakeholders and specific topics or areas. Materiality is also understood in a financial sense: the investment must carry a weight proportionate to the ROI (Return on Investment). Materiality in general is fundamental.

Sustainability strategies vary from company to company. The approach must always correlate with the materiality of the impacts generated, because those are what must be addressed.

Companies across different sectors that adopt standard, “homogenized” approaches in sustainability management likely do not conduct a clear analysis of their impacts (double materiality), stakeholder expectations, the actual risks they face and where they face them, nor future regulations, which represent a fundamental driver alongside customers and suppliers. Pirelli, by contrast, adopts a strategic approach to sustainability rather than a superficial or standardized one.

The company's strategic vision also emerges in its history of sustainable reporting. Pirelli's first report was the environmental report of the year 2000: this because it is a matter of strategy and not of mere CSR. From 2006/2007 they started with the integrated report on the basis of the GRI of the time. At the GRI level, even before the CSRD, they adopted the GRI Comprehensive level, never Core. The reason for the choice resides in the breadth of reporting which, together with the transparency relating to data

and information, matched closely with the expectations of ethical finance indices (Dow Jones or, at the time, FTSE). Pirelli is still number one at a global level in the Dow Jones Sustainability Index of the entire sector not only autoparts (compared to competitors, their Tier 1), but of automotive in general.



Source: Own elaboration of Pirelli Industrial Plan

These things do not serve only to make a good impression in front of investors, to enter various funds and be “investable”. For the interviewees, the compilation of the complex assessment questionnaire of S&P Global for Dow Jones works as a real internal audit. This allows Pirelli to map its own dynamics, identifying gaps or inefficiencies. It is also possible to see where trends go, which for this company is fundamental to define risk mitigation strategies and for an anticipatory seizing of opportunities. Everything must serve a purpose: in business nothing is done without a return or a creation of value.

Similarly, Pirelli launched first tyres with FSC (Forest Stewardship Council) certification, realizing a voluntary initiative that went beyond legal requirements. Pirelli had here too a voluntary and anticipatory approach in the use of sustainable and traceable natural rubber. This

certification attests that natural rubber plantations preserve biodiversity, bring benefits to local communities and workers and guarantees the economic sustainability of forest management. Through this certification it is verified that along the supply chain there is a separation and an identification of certified material from non-certified material. In support of Pirelli's anticipatory soul, the company in 2021 precisely introduced the first tyre containing FSC-certified natural rubber and rayon, destined to be mounted on BMW X5 XDrive45e Plug-In Hybrid. Subsequently in 2024, FSC rubber was introduced also in the Formula 1 tyre range, becoming the first motorsport championship to use certified tyres. In 2026 Pirelli's target is to manage to use in all European plants this certified rubber. (*FSC - Certificazione Forest Stewardship Council | Pirelli, n.d.*)

This demonstrates that Pirelli anticipated the CSDDD and EUDR which precisely required stringent due diligence and traceability systems.

Pirelli's approach to sustainability was summarized in three main benefits: risk mitigation, the seizing of opportunities and guarantee of stability and competitiveness in the long period.

4.3.2 RQ1: Implementation of the EU Taxonomy in Pirelli

4.3.2.1 Methodology and economic activity

The taxonomy is a regulation released in 2020, which was followed by the delegated acts published on the topics of Climate Change Mitigation and Adaptation. The requirement for companies structured like Pirelli was to provide reporting within the Annual Report 2021 (in the Consolidated Non-Financial Statement pursuant to Legislative Decree 254/2016), in implementation of Regulation (EU) 2020/852 and Delegated Regulations (EU) 2021/2178 and (EU) 2021/2139.

In 2021 Pirelli found itself having to open a project workstream to understand how to manage the new Taxonomy reporting. The economic

sector of tyres was not, however, directly classified within the Taxonomy. Company managers therefore had to identify a more generic activity, arriving at identifying themselves in Activity 3.6 for their scope. As mentioned, Activity 3.6 concerns the manufacture of other low carbon technologies.

For the first financial year, a simplified and transitional regime was envisaged, so for reporting it was permitted to demonstrate only the share of eligibility (Eligibility) of the three KPIs without the need to calculate actual alignment (Alignment). In this first phase of application, Pirelli tracked its KPIs by referring to the rolling resistance classes of the European Labelling Regulation. Within the Annual Report 2021, an eligible turnover of 16% is declared regarding excellence classes A and B. This number rises to 49% by also including class C. (Pirelli & C. S.p.A., 2021)

In the company, a methodology therefore had to be created: a complex part was the initial study to understand how to approach the required disclosures. Over the years, the methodology identified by Pirelli was then followed by the few other tyre-maker companies based in Europe subject to this obligation, while non-EU competitors (such as Goodyear and Bridgestone) did not have to follow this type of reporting.

Activity 3.6 relied — and still relies — on the labelling (European Tyre Labelling - EU Tyre Labelling regulated by EU Regulation 2020/740) of tyres with respect to rolling resistance, which is one of the fundamental characteristics of the tyre along with wet grip and rolling noise. These performances are regulated by the European label (a sort of ecolabel) that indicates the efficiency class of the tyre from the perspective of fuel consumption. The higher the class (for example Class A), the lower the motion resistance of the vehicle and, consequently, the lower the fuel

consumption. This was the link to their product with respect to a topic of climate change mitigation.

Substantially, in 2021 there was a need to analyze the requirements and develop a methodology to be explained and justified: it was not a matter of reporting an activity already specifically classified and equipped with technical screening criteria prescribed for the sector, but of applying a generic activity. Within Activity 3.6 there can be companies that produce various types of goods (household appliances or other technologies); it is not specific to the tyre.

For the rest, once this methodology was developed, Pirelli already possessed a structured data collection system, born with the first sustainability report and continuously updated over time for the preparation of the integrated report (Integrated Annual Report), started around 2010. The company therefore already possessed the information material to carry out this type of reporting.

In 2021 the auditors did not have the obligation to attest the Taxonomy figures, but had to verify that the company provided the disclosures required by the regulation. Basically, Pirelli already possessed a structure of data and disclosures that traced back from old systems and over the years, from 2021 to today, it improved this data collection for the Taxonomy. It can therefore be said that in Pirelli they were already structured to collect this type of information.

The Taxonomy, substantially, was addressed in-house. The first approach was to understand what was required. Being a complex regulation, Pirelli relied on the vision of a consulting firm, especially to benefit from the network and shared interpretations. Substantially, in the initial phase for the development of the project and the methodology, the company received this support, which over the years continued with a view to risk

mitigation considering how the Taxonomy was managed by European institutions. Precisely because of this imprecise management, in the company they found themselves having the financial statements already ready and seeing the FAQs published by the European Commission with interpretative clarifications only one week before closing, in February, close to the publication of the Annual Report. It was therefore difficult to develop and address everything internally, but beyond technical skills, there was the need for an overall vision and a network that provided interpretative keys and best practices adopted by other companies. The consulting firm played an important support role to ensure these visions. The Taxonomy implementation process can be considered substantially completed. It is normal management: faced with a refinement, useful or appropriate, or a FAQ and clarifications from European institutions, the company adapts by updating the required aspects. But in general, the structure is there.

Within the Consolidated Sustainability Statement (pursuant to Legislative Decree 125/2024) present in the Annual Report, the obligations of Article 8 of Regulation (EU) 2020/852 must be respected.

The Group, not having a dedicated category, qualifies under Activity 3.6 – Manufacture of other low carbon technologies – Annex I of Delegated Regulation (EU) 2021/2139. The objective pursued is Climate change mitigation and, to be considered aligned, they must pass the technical screening criteria. The economic activity of tyre manufacturing must demonstrate that products ensure net life-cycle emissions savings compared to market benchmarks. In the majority of cases, emissions resulting from tyres are generated during vehicle use, so savings will be obtained by reducing rolling resistance (EU Reg. 2020/740). A Class A or B tyre on the European label will consume less energy or fuel and consequently emissions are reduced, without minimizing safety.

4.3.2.2 Functions involved and coordination

The taxonomy was managed as a cross-functional process. Certainly the Sustainability function is the first to be involved. By subject matter, it immediately began to interpret the regulation and, holding the governance, developed the methodology, studied the requirements and created the framework on which to build both the actual taxonomic reporting and the data collection. The other corporate functions involved are those that hold the numbers: Administration and Control, Finance, R&D which provides technical information on products, rolling resistance and homologations, Risk Management and HSE. The latter contributes to the verification of DNSH and environmental, health and safety aspects in factories.

All technical functions called upon to verify these aspects were therefore involved in the process. It is an analysis that includes many corporate functions, both for data collection and for the verifications necessary to validate the analysis. The documents attest that this coordination relies on an established structure in which all functions and bodies collaborate with each other. At the head of this structure is the Board of Directors which annually updates the double materiality analyses, approves the targets of the sustainability plan (integrated into the industrial plan), oversees risk management and elaborates incentive plans. The Board entrusted the CEO with the task of controlling the implementation of strategies, stakeholder management dynamics and the internal control system.

The Sustainability Committee offers its support to the BoD in the analysis of sustainability trends, the evolution of social responsibility and long-term value creation. Finally, closing this first level is the Control, Risks and Corporate Governance Committee (ARCGC) with its fundamental help in the periodic evaluation of the internal control system and ESG risk management.

The Sustainability Department instead oversees the definition and monitoring of sustainable development plans, is required to report directly to the Chief Executive Officer and acts as a hub between committees and operational lines. To ensure that ESG objectives are applied, Pirelli makes use of a dual coordination structure: the Sustainability Working Group and the Network of Country Sustainability and Diversity Managers. The former deals with horizontal coordination to ensure the alignment of functional projects with ESG standards; while the latter deals with vertical/geographical coordination, local figures who have the task of establishing sustainability plans and standards in the various worldwide production sites.

The extension of sustainability into corporate decisions is assigned to specialist functions. The Finance & Administration Department with the CFO is responsible for attesting the Consolidated Sustainability Statement and compliance with the EU Taxonomy KPIs. The Risk Management (ERM) function deals with mapping risks related to water stress and climate change in an anticipatory way, evaluating the economic-financial impact of physical risks (acute and chronic) and transition risks. The management of compliance with environmental and safety performances in the group's industrial sites is managed by the HSE (Health, Safety and Environment) function, which operates through ISO 14001 and ISO 45001 certified management systems, in addition to defining guidelines for the elimination of hazardous substances.

In order to ensure transparency, reliability and completeness in reported data and processes, the governance structure provides for a multi-level control. An Internal Audit is present to verify that procedures relating to ESG data have been applied appropriately. Subsequently, the control of the process of preparation and publication of the sustainability reporting

is entrusted to the Board of Statutory Auditors. Finally, it passes through an Audit Firm for independent assurance.

4.3.2.3 Information systems

Information systems to collect all environmental data have always been necessary. These systems help precisely in the day-by-day management of the activity. On the environmental side, the information was present, and the same applies to management control. Pirelli knew exactly how many tyres were sold in the year, how much revenue they generated, what characteristics they have, also on the side of environmental KPIs.

Initially, the company had to integrate information from Controlling — linked to the company's profit and to the list of sales (namely the sum of revenues) — with another type of information not strictly financial, such as rolling resistance, the responsibility for whose product development and testing lies with R&D.

There was therefore an initial integration in a bridge system that allowed filtering data by drawing from the two existing systems; over the years, then, the process was completely integrated into the reporting managed on SAP. In recent years, there has been a transition to a digitalization of KPIs: within a structured system for the reporting of the sustainability statement, a collection of elementary data with the automatic calculation of KPIs was defined. The system simply goes to retrieve the necessary information from the various archives and provides it already verified and validated. This system serves precisely to ensure a multi-level validation of the disclosure and of the data. Previously, in fact, the Sustainability function collected information via direct request and carried out the calculations subsequently by inserting the values into Excel sheets.

4.3.2.4 KPIs and reporting (Revenues, CapEx, OpEx)

The Taxonomy requires the three financial KPIs — Revenues, CapEx and OpEx — in the two forms of eligible (eligible) and aligned (aligned). Substantially, it is asked, with respect to the totality of company revenues, which are eligible based on the classification of the chosen economic activity (Activity 3.6) and, subsequently, what share of these eligible revenues is effectively aligned with the Taxonomy through the application of the technical screening criteria (Technical Screening Criteria). The latter are the first pillar that an activity must overcome to demonstrate being aligned with the Taxonomy.

An activity or product is eligible when it falls within the scope of activity 3.6 of the EU Taxonomy; the latter will be considered aligned when it simultaneously complies with the 3 conditions of: substantial contribution, absence of significant harm to the other environmental objectives (DNSH - Do No Significant Harm) and minimum social safeguards (Minimum Safeguards). Regarding DNSH, Pirelli is evaluated on the objective of climate change mitigation (one of the six environmental objectives of the Taxonomy) and must ensure that the activity does not cause significant harm to the other five objectives, such as the management of water resources, circular economy, and pollution prevention. The activity must therefore not generate a benefit in emissions reduction at the expense of a worsening on the water objective.

On the basis of these objectives, Pirelli calculates and publishes the three mandatory KPIs. The approach used by Pirelli has always been one of safety: if an information could not be obtained correctly or through certain methods — especially regarding investments, CapEx and OpEx carried out at the local level —, that data was not considered aligned from the point of view of the precautionary principle.

As for the denominators of the Taxonomy KPIs, all values of the group consolidated figures (Total Revenues, Total CapEx, Total OpEx) are certified numbers derived from the financial statements and management control. What they put in the numerator are data present in management and control systems; it is enough to set a filter in the system to identify which shares of revenues deriving from tyres sold in the year effectively fall into the relevant performance classes (A or B) of rolling resistance and perform the selection. Therefore, the denominators derive from the group's consolidated financial statements and from the system, thus they are certain and verified. While the numerators require specific filters and methodologies.

There are then other disclosures, for example investments and operating expenses incurred in the R&D area and in the plants area. For R&D, an internal evaluation is conducted based on the number of homologations carried out during the year in order to allocate the share of R&D operating expenses dedicated to the development of tyres considered aligned with the Taxonomy. Also in this case, suitable rules were defined over the years, always considering that there was no explicit reference in the regulation to the specific activity of tyres, making it necessary to identify the most appropriate methodology. In 2025 the target set at 35% of Class A or B Rolling Resistance tyres placed on the market was exceeded, reaching 39.5%, thus determining a good share of aligned turnover. For 2030, the target set by the industrial plan is to place over 50% of these tyres on the market. Still with regard to 2025, expenses related to R&D were equal to approximately 4.6% of sales (approximately 312.7 million euros), of which 299.5 million belonging to High Value (5.6% of High Value revenues). These resources contribute to the virtual development of products (Virtual Compounder and simulations) and research into materials different from those of fossil origin, thus enabling the

development of tailor-made tyres for EV and Hybrid vehicles. (Pirelli & C. S.p.A., 2025)

While for investments at the plant level, within the investment of the production site it is necessary to select the share that reflects the requirements of the Taxonomy. This process was refined over the years by sending local reporting sheets to local teams to describe what activities were carried out. Pirelli proved to be ready right from the start and the precautionary approach always adopted ensured that values not duly validated were never included. Investments in industrial plants are not all considered 100% sustainable, but are analyzed item by item, distinguishing between: Core productive investments CCM 3.6, Specific plant efficiency investments CCM 5.2, 7.3, 7.5, 7.6 and PP 2.4.

In the industrial plan, instead, a capital allocation plan is defined to support operational transformation. The budget made available for these factory activities is highlighted. They range from Plant Energy Efficiency Projects, with over 90 projects distributed across the various factories and 50 million euros allocated in the 2022–2025 period, to the Electrification of Sites (The Elect Factory), with a CapEx of 22 million euros per year between 2024 and 2030. The overall share of investments dedicated to sustainability and technology innovation rises from 53% in 2023 to 63% in 2024, reaching 64% in 2025. This metric does not coincide with the KPI relating to the CapEx aligned with the EU Taxonomy, but concerns the industrial spending plan on which the path towards taxonomic alignment rests. (Pirelli & C. S.p.A., 2024)

The reporting of the EU Taxonomy's KPIs is carried out in line with the rules of Annex V of Delegated Regulation (EU) 2023/2486. In addition to activity CCM 3.6 that generates eligible and aligned Turnover, other ancillary activities are considered in the Group's CapEx and OpEx. These include CCM 5.2 water management, CCM 7.3 and CCM 7.5 on the

energy efficiency of buildings, CCM 7.6 renewable energy plants, PP 2.4 remediation of contaminated sites and CCM 6.4 sustainable mobility.

For Turnover, in the denominator the total consolidated net revenues from sales and services equal to 6,776.2 million euros is used, while in the numerator there is the aligned Turnover equal to 2,733.5 million euros (40.3% of the total). This number derives from tyres that simultaneously comply with the technical screening criteria (rolling resistance and wet grip classes A/B), the DNSH and the Minimum Safeguards. (Pirelli & C. S.p.A., 2025)

CapEx uses in the denominator the total additions of tangible assets (IAS 16), intangible assets (IAS 38) and right-of-use assets from leases (IFRS 16) equal to 532.6 million euros (divided into 419.7 million for tangible/intangible investments and 112.9 million € for right-of-use assets). In the numerator is the aligned CapEx of 215.99 million euros (40.6% of the total) deriving mostly from activity 3.6 and the remainder from the other activities. (Pirelli & C. S.p.A., 2025)

Finally for OpEx, in the numerator is placed the aligned OpEx of 132.30 million euros (31.9% of the total), deriving here too mostly from activity 3.6. While in the denominator is reported the total of non-capitalized direct costs deriving from R&D, maintenance/repair of plants and buildings and short-term leases equal to 414.52 million euros. (Pirelli & C. S.p.A., 2025)

As anticipated, the Technical Screening Criteria considered for CCM 3.6 are the achievement of the high classes A or B of Rolling Resistance in conjunction with the achievement of the same classes in the scope of safety (Wet Grip). The DNSH is then verified, namely compliance with the remaining environmental objectives, the absence of harmful substances and the adoption of TNFD LEAP biodiversity plans and compliance with regulations on emissions and water discharges. Finally, the last check

consists of the Minimum Safeguards, compliance with OECD guidelines, UN principles on business and human rights and ILO conventions along the chain.

There are also shares considered excluded. These include those covered by the Taxonomy but, for example, do not comply with the technical requirements (classes A or B) or the DNSH, and those that are not present at all in the delegated regulations. 32% of turnover represents eligible but non-aligned revenues. They derive from tyres that are classified with class C or higher of Rolling Resistance (D, E) or belong to a Standard segment that, although falling within activity 3.6, do not overcome the restrictions of high classes. The excluded share of CapEx and OpEx consists of machinery, moulds, maintenance/R&D destined for plants or lines that produce both aligned and non-aligned products, preventing precise distinction. Regarding the DNSH, this requires analytical evidence attesting the absence of hazardous substances and compliance along the entire supply chain; consequently, batches lacking exhaustive information are excluded.

These pieces of evidence demonstrate the difficulty created by the European taxonomic framework. With very strict Technical Screening criteria, while for eligibility one looks at the sector of belonging, for alignment instead these criteria come into play, excluding the majority of standard productions. The DNSH and the Minimum Safeguards require extremely detailed monitoring of suppliers and material composition to avoid encountering issues.

Financial Indicator (KPI)	Main Economic Activity	Total Denominator (€/mln)	Aligned Numerator A.1 (€/mln)	Eligible Share 2025 (Eligible A.1+A.2)
Turnover	CCM 3.6 (Manufacture of low-carbon technologies)	6776.2	2733.5	72.30% (€4,902.50 mln)
CapEx	CCM 3.6 (+ renewables, efficiency, water)	532.6	215.99	75.70% (€403.38 mln)
OpEx	CCM 3.6 (Compound R&D and maintenance)	414.52	132.3	54.80% (€227.16 mln)

Financial Indicator (KPI)	Aligned Share 2025 (Aligned A.1)	Aligned Share 2024 (Year N-1)	Eligible Non-Aligned Share (A.2)	Non-Eligible Share (B)
Turnover	40.30%	35.77%	32.00% (€2,168.90 mln)	27.70% (€1,873.70 mln)
CapEx	40.60%	36.61%	35.20% (€187.39 mln)	24.30% (€129.22 mln)
OpEx	31.90%	34.67%	22.90% (€94.86 mln)	45.20% (€187.36 mln)

Source: Pirelli Annual Report 2025

CapEx presents the highest alignment value of the other two KPIs. It is a strategic lever for the generation of higher sustainable turnover in future financial years. Moreover, Turnover is almost equal to CapEx, which means that the Group demonstrates that projects do not remain something experimental, but are translated into compliant products for the market. CapEx has an extremely anticipatory nature. The growth of alignment indicates that priority is given to industrial adaptation rather than to the

alignment of turnover, for example with the launch of projects to renew production lines, electrification of vulcanization plants and introduction of machinery for low-friction tyres. This occurs because through electrified and innovative structures it will be possible to further expand the portfolio of products placed on the market that can be considered aligned and consequently they will drive the growth of aligned revenues in the long period.

The gap between eligible and aligned CapEx of 35.10 p.p. finds explanation in what was said before: some machinery works in mixed production lines, consequently, based on taxonomic rules, if an investment does not belong exclusively to a compliant line it will be considered as non-aligned in a prudential manner.

Regarding the gap in Turnover, this is 32 p.p. This reflects market demand which still covers tyres belonging to class C or lower of Rolling Resistance or belonging to the Standard class.

Finally, the gap between eligibility and alignment of OpEx is the smallest; this is due to the fact that already many eligible investments are directed towards sustainable projects, reducing their dispersion into non-aligned activities.

EU Taxonomy KPI	Metric	2021 (Eligibility Only)	2022	2023	2024	2025
Turnover (Revenues)	Eligible (%)	16.0% (49% with Class C)	63.00%	67.00%	68.60%	72.30%
	Aligned (%)	— (Not Applicable)	25.00%	32.00%	35.80%	40.30%
CapEx (Capital Expenditure)	Eligible (%)	12.0% (22% with Class C)	30.00%	75.00%	74.80%	75.70%
	Aligned (%)	— (Not Applicable)	23.00%	34.00%	36.60%	40.60%
OpEx (Operating Expenditure)	Eligible (%)	10.0% (22% with Class C)	30.00%	32.00%	55.40%	54.80%
	Aligned (%)	— (Not Applicable)	23.00%	23.00%	34.70%	31.90%

Source: Own elaboration of Pirelli Annual Reports 2021-2025

Aligned Turnover demonstrates a continuous expansion over time, +15.4% in 4 years, demonstrating the commitment is aimed at directing products sold toward the High Value and Eco & Safety range. Alignment also reflects the increasingly important presence of tyres with dual class A/B on the European label.

Aligned CapEx is also in constant growth since 2022. In terms of eligibility, instead, an enormous jump is made between 2022 and 2023. Many investments concerning production hubs were included in activity CCM 3.6; furthermore, those related to renewable sources and energy efficiency also increased.

For OpEx, instead, there is a paradox: in the scope of alignment there is constant growth until 2024, then in 2025 this percentage drops slightly. The reduction is due to the fact that the denominator increased because of the increase in development and industrial maintenance costs.

As observed for the single year of 2025, also across the entire time span CapEx grows more than Turnover, up to then converging in 2025. In 2022 it can however be noted that aligned Turnover is higher than aligned CapEx. The reasons are two. The market was already existing and mature, Pirelli already commercialized a portfolio of products containing within it very efficient High Value tyres, so substantially turnover reflected the immediate sales of these products compliant with screening criteria. The other reason is linked to learning and the search for the new methodology: in 2022 Pirelli adopted a prudential mapping of KPIs, limiting itself to assets attributable only to A/B product lines. Another point was the partial availability of documents relating to non-EU plants; in fact, a large part of industrial investments that could have been aligned was left out. However, from 2023 Pirelli started to integrate Taxonomy and industrial planning, causing eligible CapEx to increase from 30% to 75%. Capital investments (lead indicator) aimed at increasing production capacity anticipate the future expansion of sales (lag indicator).

In the notes at the bottom of the tables Pirelli specifies the exclusion of Class C tyres, because they are not qualified as the best available technology on the market belonging to CCM 3.6, they would raise alignment values fictitiously, consequently they fall into eligible but not aligned shares. In the first years of application of the EU Taxonomy, the classes establishing a boundary of alignment were not specified, Pirelli's competitors could therefore have included Class C to demonstrate being much greener. Pirelli however preferred to remain faithful to its prudential approach and avoid running into Greenwashing, reporting lower but untouchable numbers.

4.3.3 RQ2: Organisational challenges and managerial responses, creating long-term value

4.3.3.1 Compliance and reporting challenges

The integration with the other regulations, precisely, does not start from scratch, but the company has behind it a long history of reporting relating to the environmental report and the integrated report. With the advent of the CSRD — rather than other regulations as they were conceived before being in the revision phase — the reporting requirements were simply inapplicable by 90% of companies, while for that 10% of extremely advanced companies like Pirelli they were applicable only with extreme bureaucratization. The issue with these regulations is that they are correct from the point of view of vision: the fact that one must arrive sooner or later at the timely application of the regulation, the total reduction of emissions, that there must be a well-executed due diligence on the supply chain with relative co-responsibilities and a comparable (benchmarkable) reporting among various companies with respect to the actual materiality of their impacts, is all correct. But these rules were written without looking outside, consequently they resulted inapplicable. What legislators obtained was a rejection by 90% of companies (certainly not by Pirelli, which is obliged to report because it is listed, etc.). Now the moment is useful for European legislators, to review timing and methods, and above all pay close attention when making certain laws: there must be feasibility studies at the local level and concrete support for companies.

The CSRD resulted in the fact that for Pirelli's report — which until two years ago was perfectly readable, coherent and comprehensive — the obligation arose to specify for each topic: policies, actions and targets. This leads to finding oneself with 300-page reports in which the PAT (Policies, Actions, Targets) scheme continues to be repeated depending on the point addressed, making the document unreadable and cumbersome.

This scheme reflects the mandatory structure of the ESRS (European Sustainability Reporting Standards). Under Policies falls the formalization of guidelines by top management, Actions include those interventions, both industrial and economic, that have been put in place in order to mitigate impacts and manage risks. Finally, the definition of standardized ESRS objectives and metrics to measure these in the short and long period belongs to Targets. For future reporting standards it seems however that legislators have realized that the situation was getting out of hand; there will therefore be the possibility to streamline the structure and make it much more usable. For a listed company, the report remains a reporting and compliance tool whose primary stakeholder is the financial market, which requires precision. External communication passes through brochures, website and other channels: it is not the report that is the primary communication tool, also because, due to regulations, it would result unreadable. The new standards attempt to review its structure and Pirelli will be ready to adapt immediately.

Given that all regulations have made the report unreadable, Pirelli decided to focus on other communication strategies. The report was already originally a technical tool rarely read by the end customer; with the CSRD it ends up being consulted, and even with difficulty, almost only by analysts. It is clear that sustainability communication must pass through somewhere, but in general communication itself is a strategic lever. It is necessary to select the reference stakeholder and identify the most effective way to convey what interests them. The methods are multiple and range from social media to the website. The report remains a tool tailored to investors.

The same logic cannot be applied to all companies: in the case of a listed company like Pirelli it works like this, while in the case of an unlisted medium-sized enterprise, there being no CSRD obligation, the report can

continue to represent the main communication tool. It always depends on the compliance obligations to be respected. In the context of Pirelli, it remains a document destined for investors.

According to one of the interviewees, one of the first versions of the CSDDD (Corporate Sustainability Due Diligence Directive) wanted the company to take responsibility over the entire supply chain up to the upstream, that the same responsibility be taken by the supplier toward further upstream and so on for every link and sub-supplier of the chain. It would have been too large an expansion and an unmanageable responsibility, making the regulation non-implementable in medium-sized companies (which are the large part). Furthermore, legislators did not even provide guidelines on how to implement what they required in the regulation, exposing companies to the risk of being attackable by any stakeholder claiming that the company was not doing enough. This was the way in which the various current laws were managed (CSRD, EUDR for deforestation), spending millions to set up these systems. Regulators today ask to set up a bureaucratic system of millions of euros in which the company must provide an assurance that everything is in order along the supply chain, despite Pirelli, for example, having already implemented certification such as FSC in such a way as to anticipate these requests.

Furthermore, it is highlighted how this type of report results anti-competitive, since it has forced European companies to structure very expensive systems, while Pirelli's direct competitors — as a global company — are not subject to the same obligations. They do not have the obligation to introduce the bureaucratization of systems and processes that Pirelli was required to implement. Unlike Pirelli, competitors like Bridgestone or Chinese manufacturers are not required to do all this.

Germany even considered not transposing the directive; the main industrial associations and parts of the government raised very strong

protests against the bureaucratic burden and costs of the CSRD and CSDDD, arguing that they would damage the competitiveness of businesses and the fabric of German SMEs (Mittelstand). All these clashes slowed down the transposition of the directive by German industries. In summary, all this is the result of the approach given by the previous European legislature; now it is necessary to verify how the framework will evolve with the current jurisdiction. It is not a matter of doing deregulation, but rather of elaborating a regulation that is applicable and formulated with sound judgment, considering that it must be concretely applied by companies.

The problem is upstream. The Commission wrote a directive that provided for technical data and the repeated “policy, actions, targets” structure, without real consultation; this structure was defined by the directive, not by EFRAG. The latter, in line with the Commission (the client), carried out a formal stakeholder engagement activity. When the parties were consulted — not all and not in the best way — and these highlighted that the regulation was unfeasible or unclear, instead of reducing the KPIs to overcome the unfeasibility, the result was a further increase in indices. This was the mistake.

For Pirelli, there were no huge investments or significant costs directly attributable to the taxonomy. Pirelli's strategy is guided by a continuous path of development and growth, corporate targets do not depend intrinsically on the Taxonomy itself, but on the analysis of material impacts, the definition of strategy, risk mitigation and seizing market opportunities. In line with this, investments that must be made are fully implemented, but not for reasons directly connected or cause-and-effect with the taxonomy.

In general, it is predominantly a matter of compliance and reporting issues. For Pirelli, corporate strategy stems from its own business, market and

materiality assessments, and is not directly dictated by the regulatory requirements of the Taxonomy.

4.3.3.2 The Taxonomy as a product driver

The company does not limit itself to mere compliance with the regulation, it does not set its product objectives only because the law requires it, but rather creates a link between the latter and its own industrial strategy, thus confirming that Pirelli had already undertaken this path independently. The introduction of the Taxonomy substantially also guided the definition of product targets. If the taxonomy requires efficient products from the perspective of rolling resistance, it becomes a driver: to increase the share of revenues aligned with the Taxonomy, the products to be developed in subsequent years must follow this guideline. If the company believes that products with a high class of rolling resistance are demanded by the market (customers and partners), it is necessary to define multi-year growth targets aimed at expanding the offering of this type of tyres in the product portfolio. The difference, substantially, was having an external input based on regulatory and market expectations, which contributed to orienting the corporate strategy, especially at the product level. The development of these products is based, in addition to strong demand from OEM customers, also on an Eco-Safety Design approach, aiming to maximize ecological performance without ever sacrificing safety.

The progress and growth of aligned revenues are then measured through investments dedicated to the development of such products and the evolution of the portfolio.

4.3.3.3 Impact on relations with investors and ESG rating agencies

At the rating level, taxonomy metrics are now requested by almost all interlocutors. The regulation provides for standardized templates included in the Annual Report. This refers to standardized disclosure tables provided for by the Delegated Act on Article 8 of the EU Taxonomy.

Therefore, all companies subject to European disclosure use the same representations. The presence of templates facilitates data comparability by analysts and ESG rating agencies. This helps to access sustainable finance instruments (Sustainability-Linked Loans or Green Bonds); in fact, in 2025 Pirelli reached 100% of bank debt in Sustainability-Linked format with credit margins linked to Scope 1, 2 and 3 targets. The company was also the first in the sector to adopt this Sustainability-Linked Financing Framework in 2022 and subsequently to issue the benchmark Sustainability-Linked Bond in 2023 of 600 million euros.

Specialized analysts expressly request this disclosure, analyzing it in detail, while more generic analysts limit themselves to verifying whether the company falls within and meets the criteria of the EU Taxonomy. In general, ratings do not look only at the EU world; therefore, on this side Pirelli benefits from a competitive advantage over non-EU competitors, which are not required to provide such a degree of disclosure. For analysts and rating agencies, the disclosure provided by Pirelli results extremely clear and structured. On the side of investors and credit institutions, taxonomic reporting constitutes an element that, combined with other factors, increases corporate credibility in the presentation of strategic plans and planned investments. In 2025 Pirelli obtained a score of 86 points in the S&P Global Corporate Sustainability Assessment (the highest in the Automobile and Auto Components sector with relative inclusion in the Top 1% of the Sustainability Yearbook), is then present in the CDP Climate A List, the Platinum level of EcoVadis, and finally obtained a Negligible Risk / Top Score evaluation from Sustainalytics.

4.3.3.4 Supply chain and stakeholder management

Since 2006 Pirelli has included ESG clauses within contracts, developing supplier ESG selection criteria that today have reached a high level of evolution. In addition, on-site audits managed by independent third parties

and financed by Pirelli are conducted to verify operational conditions in the field at suppliers, especially during the homologation phase.

The management of sustainability in terms of the supply chain is absolutely integrated across all phases: from scouting to selection, from product homologation to the contractual phase up to the continuation of the relationship during the supplier's activity. In Pirelli's Industrial Plan specific targets linked to the ESG risk assessment activity are defined: specifically, an increase in risk assessment coverage up to 98% for Medium Risk suppliers and 100% on High Risk suppliers by 2027 is expected on purchases made from all suppliers classified as medium-high risk, precisely because the company always operates with a view to materiality. This is very much appreciated by investors because it conveys an idea of control and solidity regarding these supply chain risk management issues. In 2023 coverage reached 96% for High ESG Risk suppliers and 90% of Medium Risk suppliers.

With a view to capacity building, Pirelli provides its suppliers with specific training modules bearing their costs, such as courses on Business and Human Rights and Nature & Biodiversity. The company also requires and incentivizes the cascading of these skills and requirements along the sub-supply chain of the suppliers themselves, so that the protection of ESG standards extends upstream along the entire value chain.

Pirelli has also set the Net-Zero target for 2040, attested/validated by the Science Based Targets initiative (SBTi); it is the most challenging and ambitious target in the automotive sector globally, therefore not only the tyre sector. Since the impact of Scope 3 is strongly significant, the company promotes intense supplier engagement activity for the reduction of absolute supply chain emissions in support of the 2040 target. Dedicated assessments are conducted not in an inspection or audit logic, but of active engagement, aimed at identifying suppliers' ability to manage risks and

opportunities related to climate change. For several years Pirelli has adhered to the CDP Supply Chain program, within which it continuously obtains the A-List qualification in terms of supplier engagement capability. It is defined as a mature system, but under continuous improvement.

4.3.3.5 Product innovation, material-related trade-offs and the use of third-party certifications

Sustainable materials certainly weigh from the economic point of view. The fundamental point is that Pirelli products maintain, due to their positioning, very high quality and technology. Therefore the introduction of new materials requires tests and validation each time. It is an enormous cost because of trials and tests. The homologation of a new material sometimes lasts more than a year, representing already in itself a huge cost; furthermore, the type of raw material that Pirelli looks for on the market is not the classic recycled or renewable material that is fine for the mass-product (mass-market).

The Pirelli product must have very high quality; there is always an effort to engineer the product with a view to maximizing environmental performance, without ever compromising safety. Certain materials on the market have characteristics that can be fine on a mass-market tyre, but are certainly not suitable for the Pirelli tyre which must go at high speeds, and basically are not fine either for its positioning of excellence.

For the company the issue therefore arises of the extension of the supply chain and of the availability on the market of high-quality recycled materials. Raw materials with such characteristics have high costs, but Pirelli adopts a strategy that allows testing and introducing them gradually, guaranteeing the presence on the road of tyres at the top of the category for content of recycled and renewable materials. Every year an innovation is introduced that acts as a forerunner, allowing a progressive cascading (extension) of innovative solutions to all the rest of the tyre park. Their

target is to develop a tyre with a high percentage of bio-based and recycled materials to acquire know-how and experience in the field, then transferring the results to global production. These innovative materials allow increasing tyre durability by reducing the tread wear rate, going from -23% in 2025 to a future -30% for 2030, an anticipatory factor relating to emission limits of the EURO 7 standard. All these innovations regarding materials are developed through an Open Innovation network.

The difference between Pirelli and its peers (the main competitors) is that the company has already placed on the market a product with more than 70% renewable and recycled (bio-based) materials, certified and on the market to equip a fleet. This product is the Pirelli P Zero E, it was introduced as the first UHP (Ultra High Performance) tyre to have such a high percentage of bio-based material (silica deriving from rice husk ash, circular carbon black, recycled steel and natural rubber with FSC certification). The third-party certification refers to the ISO 14021 standard on the traceability of environmental claims. Pirelli uses this element to differentiate itself from its competitors who communicate similar percentages, but on concept tyres not destined for sale. Peers, therefore, are at the concept, at the vision and perhaps not yet certified.

Another very important characteristic of Pirelli from a strategic perspective is third-party certifications for every claim or activity. The company does not rely on self-declarations, but an independent third party attests the veracity of the statements.

Since this strategy was adopted in Pirelli, it was noted that the percentage numbers of bio-based and recycled materials declared by peers went down compared to those of the previous year; they published different numbers. Pirelli, to avoid and contrast greenwashing, chooses the path of certified external validations.

Pirelli's approach to certification is distinguished from that of report assurance alone. One thing is assurance of a report, another thing is voluntarily seeking an independent third-party certification that validates the company's claims. When Pirelli declares that a product has a certain percentage of recycled bio-based material, or that its supply chain management system is fully aligned with ISO 20400 (Sustainable Procurement Guidelines), it means that this was confirmed by audits conducted by an independent third party. ISO 20400 indicates that procurement processes and supplier management are aligned with international guidelines for supply chain sustainability. In general, Pirelli avoids self-referencing and strongly seeks these external verifications, given that it finds it competitive precisely thanks to its own seriousness to create this barrier on the market and towards peers. Pirelli has a chain-of-certifications where, on a six-monthly or annual basis, subsidiaries issue these formal statements attesting to the reliability of the non-financial data they transmitted. The CFO is responsible for attesting that the Consolidated Sustainability Statement is prepared in compliance with ESRS and Article 8 of the EU Taxonomy, and then obviously there will be another check by the internal audit.

Under the technical profile, modifying a single ingredient in the compound requires the redesign of the entire chemical formulation; it is therefore a truly enormous effort, both on the formulation side and on the testing side. Safety, as said before, is the very first thing, but performance is just as important. Therefore, to maintain the same level of performance if there is a change of supplier or of a component, the result will not be the same. There will be a need to review the entire formulation to keep characteristics unaltered. This, therefore, means an enormous effort of people, time and money, because tests cost.

Pirelli however managed these constraints through the development of a balancing strategy, introducing products and materials gradually, accompanied by advanced work of the R&D function. In particular, the Research and Development department integrated artificial intelligence tools and digitalization, such as simulation and virtual development (virtual design of the tyre) to try to reduce the number of physical tests. Since tests are conducted only in certain periods of the year and on certain proving grounds, the limited availability of such tracks represented a bottleneck. Relying on digitalization and simulation greatly sped up development and allowed collaboration with car manufacturers for the realization of Perfect-Fit products (customized and homologated tyres for specific car models), achieving positive impacts also on the replacement market.

The analysis of environmental performances is carried out through advanced digital tools, such as the Virtual Compounder which researches lowest-impact compounds and LCA platforms extended to all new product lines to keep track of the various impacts.

4.3.3.6 Environmental impact of products along the life cycle

Life cycle analysis is fundamental and is something distinctive for Pirelli. The company has been developing LCA studies for some time for the determination of the Carbon Footprint, progressively integrating also the measurement of the Water Footprint and the Biodiversity Footprint. The latter represents a new methodology of recent implementation by Pirelli; despite regulations being quite new to provide support, Pirelli wants to be innovative and maintain the front row on these topics and for this reason they are investing resources.

The preparation of the LCA is also required of the most impactful suppliers, and both that of the suppliers and of Pirelli is required to be certified. The aspects of decreasing the product's environmental impact are

based on the use of materials with an ever lower carbon footprint (because recycled or because natural) in replacement of fossil materials. The benefits, therefore, are quantified analytically through LCA analyses.

Pirelli reports Scope 1 and Scope 2 emissions regarding its factories. Regarding Scope 3, 85% of overall emissions, according to the GHG Protocol, is attributable to the supply chain, in particular to the materials procurement phase. It is here that the corporate strategy closes the circle.

Finally, Pirelli also works on the end-of-life with innovative projects. Although in Europe and in most of the world the management of end-of-life tyres (ELT) is heavily regulated, the end-of-life tyre constitutes a source of noble materials to recover. Consequently, innovations to reuse materials also increase. Pirelli itself works to incentivize the recovery of pyrolysis oil from end-of-life tyres (ELT) to reuse it within the company with its own products in ad hoc projects.

While underlining that the end-of-life phase impacts in a minimal share on the overall Carbon Footprint of the life cycle of the Pirelli product, the balancing between quantity and quality of the recovered raw material remains a strategic priority for self-recycling.

The approach to the circular economy is based on the use of the 5Rs (Refuse, Reduce, Reuse, Re-Think, Recycle). For the management of ELT, Pirelli participates in the initiatives of the Tyre Industry Project (TIP) and Tyres Europe.

Regarding social LCA, the company applied it on an experimental basis to a specific subsidiary, given the lack of shared standards. If for environmental aspects many standards and clear indications exist such as GHG Protocol, in the scope of Social LCA there is still excessive methodological fragmentation and room for inventiveness. Pirelli plans to express creativity in business strategies, but not in public reporting. The

Social Assessment for Pirelli is given by the satisfaction of reference stakeholders regarding social-type aspects such as: employee satisfaction, the reduction of the injury frequency rate, employee engagement, the economic and social contribution to related industries and local communities, as well as the mitigation of risks of human rights violations along the supply chain, particularly in developing countries. Pirelli makes use of numbers that are solid. Pirelli has first-rate systems that are ready to calculate product LCA and that they have been using for years. On the social front, until official and unambiguous guidelines are defined, the company will maintain a cautious position, relying exclusively on solid and attestable KPIs.

4.3.3.7 Stakeholder engagement and internal organizational integration

As regards external partners and suppliers, the integration of sustainability is now part of the corporate strategy.

On the supply chain, when the requirement of certain requisites creates a cost for suppliers, it is necessary to strike a balance, which is why Pirelli works extensively at the level of supplier engagement. Regarding materials, Pirelli works extensively with a view to co-development, Joint Development. It develops innovative products with suppliers that also become an advantage for the suppliers themselves and a great advantage on the market. Obviously, it is unthinkable to impose on the supply chain to instantly adapt to perfect standards and to be certified on everything. This approach reflected, if anything, the rigidity of the European legislative approach of a few years ago.

Within the company, no particular resistance occurred. The Sustainability function was introduced in Pirelli in 2008, within a pragmatic culture attentive to numbers. All ESG initiatives and innovations undertaken have always been supported by a formal Business Case. In the company there is no room for purely theoretical approaches, but solid, historical values

and strong managerial attitudes prevail, aimed at correlating each action with impacts, advantages, numbers, mitigated risks and measurable results. This method allowed a fluid and continuous integration of every innovation.

The internal skills of people are continuously updated thanks to Board Induction sessions relating to developments in ESG regulations and to the results of Double Materiality. Training activity records an average of 7.4 days per year per employee with a focus on digital transformation, safety and environmental skills. The various metrics relating to corporate climate and sense of belonging are measured through the Global Sustainable Engagement Index, recording an approval rate equal to 83%, even better than the target set at 80%.

ESG targets have certainly been for many years in the short-term incentive systems (Short-Term Incentives - STI) and long-term incentive systems (Long-Term Incentives - LTI). However, these systems do not reward reporting or alignment with Taxonomy standards. It is results and performance that are considered within the scope of their short- and long-term incentives.

A fundamental element is represented by the CEO's Vision: the presence of a top management with clear ideas is a necessary condition in order to drive change and promote innovation in any area of the company.

It was therefore not complex to advance sustainability in the company, provided these caveats are respected, namely giving the right interpretation of the company's culture in introducing innovations in these terms.

4.3.4 Documentary comparison

The present information provided in the interview phase finds confirmation in the Group's public documents. The joint analysis of the

documents highlights that sustainability is taken to heart as a fundamental lever and not as an ancillary activity.

The anticipatory trait dates back to the nineties with environmental management systems in plants, certified ISO 14001. In 2004, moreover, the Sustainability Committee was established to address and satisfy in a balanced way the demands of different stakeholders in order to guarantee unobstructed growth for the company. Furthermore, Pirelli preceded the evolution of integrated reporting through adhesion to the United Nations Global Compact and ISO 26000 guidelines (Social Responsibility). Triumphs in the scope of external evaluations (global Top Score in the Auto Components and Automotive sectors in S&P Global's Corporate Sustainability Assessment, mentioned previously) are used as internal analysis. (Pirelli & C. S.p.A., 2024)

The Pirelli Sustainability Plan is based on five pillars to which the company commits: Planet/Climate, Nature, Product, People, Supply Chain. These integrate with specific commitments related to Customers/OEMs, Suppliers, Employees, Local Communities and Financial Community. (Pirelli & C. S.p.A., 2024)

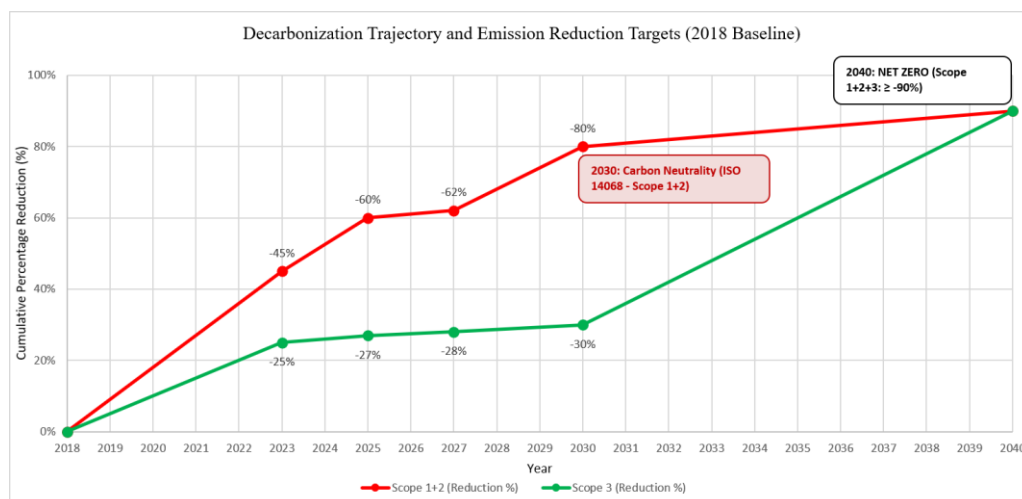
Pirelli has defined its own path (roadmap) towards decarbonization. The set objective is the most challenging in the tyre sector, validated by the Science Based Targets initiative (SBTi), in line with limiting global temperature increase within 1.5°C (established by the Paris Agreement).

The net zeroing of greenhouse gas emissions across the entire supply chain (Scope 1, 2 and 3) is expected by 2040, anticipating the global deadline set for 2050. There must be an absolute reduction of approximately 90% compared to volumes emitted in the 2018 base year. (Pirelli & C. S.p.A., 2024)

As regards Scope 1+2 Targets, a 60% reduction was achieved from 2018 to 2025 (-63.3% at the end of 2025), while with a view to 2027 an increase to 62% is expected and subsequently to 80% for 2030. Carbon Neutrality by 2030, with reference to the ISO 14068 standard, will be achieved through energy efficiency interventions and the use of alternative fuels. Only in the case of unavoidable residual emissions can compensation systems (carbon offsetting/removal) be used, to avoid fictitious compensation. (Pirelli & C. S.p.A., 2024)

A target achieved in 2025 was the total implementation of certified electrical energy from renewable sources for all production plants. Also by 2030, the “The Elect Factory” program is planned, namely the electrification of production processes by converting 75% of vulcanization presses in Europe into electric machinery.

Moving toward Scope 3 (upstream and downstream chain emissions), a 27% reduction from 2018 to 2025 (-27.5% end of 2025) was ascertained, which will increase to 28% in 2027 and to 30% by 2030, compared to 2018. The target is bound to three specific categories established by the GHG Protocol: Category 1 (purchase of raw materials and semi-finished products), Category 3 (extraction activities related to fuels and energy not included in Scope 1 and 2), Category 4 (upstream transport and logistics to plants). For 2040, the reduction along the supply chain is precisely expected at 90%. (Pirelli & C. S.p.A., 2024)



Source: Own elaboration of Pirelli Industrial Plan

Pirelli adopts the Eco-Safety Design approach to develop innovative solutions suitable to anticipate and satisfy the needs of automotive manufacturers and regulatory requirements (EURO 7 regulation for abrasion and particulate matter and EUDR regulation against deforestation).

The incidence of material of biological origin (bio-based) and recycled materials was expected at 27% by 2025 (26.9% was reached at the end of 2025). This target rises to 40% by 2030 and is projected to be higher than 80% by 2040 up to reaching 100%. Regarding their Flagship Product, the Pirelli P Zero E tyre was introduced in 2023 and made with over 55% of recycled materials certified by a third-party body (ISO 14021) and triple Class A in terms of Rolling Resistance, wet grip and noise. In 2025 (as mentioned previously) they moved to a P Zero with over 70% of recycled and natural materials, specifically 31.7% is composed of bio-based materials and at least 38.3% of recycled materials. The corporate Target is an achievement higher than 80% of non-fossil materials in the best product by 2030. For the Wear Rate, continuous improvement is expected to contain Tyre and Road Wear Particles (TRWP) with the increase in sales volumes of tyres classified in A/B of Rolling Resistance. (Pirelli & C. S.p.A., 2024)

Regarding Life Cycle Assessment and Biodiversity, 100% of new product lines integrates impact metrics into the LCA analysis. In 2025 the objective of equipping 100% of industrial sites and proving grounds with the Biodiversity Action Plan, developed according to the TNFD LEAP, was achieved. In terms of water efficiency, a reduction of up to 45% in water withdrawal per ton of product is expected by 2030 (already achieved in 2025 with -54.3% compared to 2015). A reduction of 60% by 2030 instead is expected for plants located in places with high water stress (-43.1% from 2015 to 2025). (Pirelli & C. S.p.A., 2024)

Equally important are workplace safety and diversity. The trend of injuries recorded is excellent, the index dropped to 1.21 in 2025, in line with plan targets. In terms of diversity, the company has the objective of including approximately 33% female figures in managerial positions by 2030. (Pirelli & C. S.p.A., 2024)

The Sustainable Procurement process, validated by ISO 20400, translates due diligence into concrete and stringent requirements for suppliers and commercial partners. The decarbonization of strategic suppliers of raw materials and capital goods by 2025 is required through the use of renewable energy in the production processes of components destined for Pirelli. In order to calculate upstream Scope 3, many companies resort to estimates or sector averages, Pirelli instead goes into detail. The company collects real and specific data directly from its suppliers in order to cover 90% of these emissions for accurate, solid and verifiable reporting. This control process is carried out through specialized rating and verification agencies, while for new suppliers on-site audits are conducted, with a possible remediation plan in the event that gaps in the ESG area are found.

In the field of sustainable finance, the company was the first to launch a Sustainability-Linked Financing Framework and a benchmark Sustainability-Linked Bond. Furthermore, as mentioned previously,

incentive plans exist upon achieving specific sustainability targets established by the Board of Directors, supported by the Remuneration Committee and Sustainability Committee. (Pirelli & C. S.p.A., 2024)

Finally, in the scope of Local Communities and Multilateral Initiatives, the company interfaces with the territory and communities through various partnerships with global institutions and think tanks (WBCSD, Tire Industry Project and the UN Global Compact). It also establishes collaborations with university hubs for continuous Open Innovation, therefore not only internal innovation. These initiatives transform Corporate Global Citizenship into concrete actions by focusing on three areas: training and technical skills, road safety and local development.

4.4 Case discussion

4.4.1 Introduction to the discussion

This section develops an interpretation of the empirical evidence of the company case, in order to provide a direct answer to the two research questions (RQ1 and RQ2).

4.4.2 Critical interpretation of RQ1

RQ1: “How has the European Taxonomy been implemented by Pirelli (methodology, KPIs, relationship between functions, information systems)?”

The implementation of the EU Taxonomy was not a mechanical work, but required a new methodology, especially for the identification of the activity of belonging of the tyre sector, given that a specific category did not exist. To adapt to these regulations the company had to find the best link between product performance and contribution to climate change mitigation. The methodology served to distinguish between eligibility and alignment, help with the various technical screening criteria and adapt to

the various FAQs and clarifications of the European Commission issued even close to the publication date of the financial statements.

On the organizational side a plurality of functions and internal actors are involved; therefore, the work is not entrusted to the Sustainability function alone. The organizational structure is then subject to the direction of governance functions. In this case it can be said that taxonomic reporting distributes responsibilities along the corporate decision-making and control chain. Alignment will depend on the ability of functions to integrate technical, environmental, financial and social information.

The experience of Pirelli demonstrates that the implementation of the Taxonomy was facilitated by pre-existing data collection and management systems and also by the presence of an environmental and integrated report published already for years. Moving from a manual collection system to an integrated system allowed combining controlling data and R&D technical data. Furthermore, the prudential method adopted by Pirelli contributed to strengthening the veracity and reliability of the information, contributing also to demonstrating the company's ability to manage to collect data along the entire chain. This demonstrates that the taxonomy can have different effects depending on how the company operates. In the case of Pirelli this became a lever to improve its own systems, while less structured companies may have had to build new infrastructures, processes and skills from scratch.

In summary to answer RQ1, it can be said that Pirelli managed to adopt an internal methodology to interpret Activity 3.6 within the scope of tyres, initiating a process that involves Sustainability, Finance, HSE, R&D, Risk Management and corporate bodies and continuing to evolve its information systems for the automatic calculation of taxonomic KPIs. The process was therefore made possible thanks to the capabilities developed in an anticipatory way with respect to the introduction of recent

regulations. The introduction of the European framework in fact contributed to refining Pirelli's sustainability management system rather than building it from scratch.

4.4.3 Critical answer to RQ2

RQ2: “What organisational, informational, and compliance challenges arise from the implementation of the EU Taxonomy, and how does management address them to create long-term value?”

Adapting to the EU Taxonomy, combined with the convergence towards the CSRD and the ESRS, generated challenges regarding compliance. The main criticalities that emerged from the investigation include the need to interpret regulations subsequently subject to late clarifications, the burdens linked to the adaptation of systems and third-party assurance, and also the complexity of the documents required to demonstrate compliance with the various environmental and human rights principles along the global supply chain. The obligation to follow the PAT scheme led to the preparation of documents of over 300 pages, increasing technical complexity and reducing readability on the part of non-specialized stakeholders. Only rating agencies and financial analysts can benefit from them.

A critical observation that can be made concerns the discrepancy between the objectives established by European institutions and their actual and concrete applicability by companies. As highlighted in the interview, management perceives all this as an excess of bureaucratization and indicators that risk making everything more cumbersome and unsustainable to implement on the part of the majority of companies. This translates into a competitive disadvantage for European companies compared to non-EU ones that are not subject to the same obligations.

The case analysis brings out a clear distinction between two cost categories. The first is direct compliance costs; it includes expenses deriving from accounting and legal consultancies, software updates, verifications, third-party audits and certifications.

The second is linked to sustainable industrial investments including R&D innovations and the development of new bio-based and recycled materials, electrification of plants and energy and water efficiency.

Pirelli does not directly attribute to the Taxonomy the need to carry out strategic investments. Double Materiality, market demand and OEM manufacturers' demand, but also risk management and the seizing of opportunities is what really drives the company's industrial plan and investments. In the end, however, compliance and strategy are forced to converge, because although Pirelli does not invest for pure compliance, regulation still affects these decisions. In any case, the main driver pushing the company to allocate resources is industry and competitiveness.

The value generated by management initiatives to manage regulatory complexities is summarized in the following table.

Compliance & Reporting Challenge	Managerial Response Adopted	Value Created for the Enterprise
Data dispersion	Integration into ERP systems (SAP) and automated link between Controlling and R&D.	Enhanced traceability: data reliability and elimination of accounting error risks.
Methodological regulatory uncertainty	Proprietary in-house methodology supported by an external consulting network.	Methodological consistency: robust alignment and reduced risk of audit challenges.
High costs and bottlenecks of physical testing	Adoption of Artificial Intelligence, simulation, and virtual development (Virtual Compounder).	R&D efficiency: shorter development cycles (time-to-market) and resource savings in proving grounds.
High cost of sustainable materials	Gradual introduction (balancing strategy) starting from the flagship product (P Zero E).	Learning and cascading: progressive transfer of innovations from top-tier models to global production.
Supplier compliance difficulties	Supplier engagement programs, capacity building, and Joint Development contracts.	Supply chain resilience: security of supply and shared Scope 3 decarbonisation.
Risk of ESG scrutiny and greenwashing	Voluntary independent third-party certifications (ISO 14021, ISO 20400, FSC®).	Credibility and differentiation: competitive barrier built on verified environmental claims.

Source: Binda B. (2026)

The Taxonomy also served as an indirect driver for improving product strategy, leading the company to set stringent multi-year targets to foster the growth of products positioned in Rolling Resistance classes A and B. Together with demand from Premium and Prestige car manufacturers, the Taxonomy helps Pirelli consolidate its advantage in the research into non-fossil materials.

Stakeholder management is based on the proportionality and materiality of impacts and risk. Investors and institutions receive standardized disclosure based on the Annex V template. OEM customers are involved in Joint Development aimed at developing Perfect-Fit tyres. Along the supply chain, there is a management system based on the ESG risk level, but the company also offers training initiatives. Benefits for local communities and employees are measured through specific targets; in addition to this, welfare systems and territorial conservation projects are also present.

In conclusion, the answer to RQ2 highlights that the main challenges include the interpretation of regulations, the integration of various data, auditing, reporting complexity, the management of due diligence along the entire supply chain, and the costs associated with all of this. Pirelli addresses these developments by leveraging its pre-existing capabilities, cross-functional coordination, a prudential approach towards collected data, reliance on independent third-party certifications, and continuous innovation.

These approaches used by management help create value through greater reliability, risk management, and long-term competitiveness, even though the direct contribution of the EU Taxonomy in terms of investments remains limited.

The next section will provide a comparison between the empirical evidence and the literature presented in previous chapters.

4.5 Comparison between empirical findings and theoretical frameworks

4.5.1 Shareholder Primacy, Stakeholder Theory and Stewardship Theory

According to Shareholder Primacy, management should avoid costs related to socio-environmental issues given its short-term orientation, thus creating a barrier to sustainability. (Friedman, 2007)

Pirelli offers a partial convergence with this framework. Substantially, the company does not rely on a purely ethical or abstract sustainability; every environmental initiative of the company is based on Business Cases with measurable returns. Furthermore, the management of ESG pillars is not experienced as a sort of "tax" (in Friedman's terms), but is used as a tool to mitigate risks and ensure business continuity in the long term. (Friedman, 2007)

Stakeholders are the central subject of Stakeholder Theory; attempting to balance their interests will enable companies to succeed in the long term. Recent studies show that the manufacturing sector adopts green management practices as a response to stakeholder pressures. (Athuraliya, 2024) (Freeman & McVea, 2001)

Pirelli applies Freeman's logic: not all stakeholders win simultaneously, but they are managed based on the materiality of impacts and risk. Resources are allocated pro-rata based on the severity of issues along the supply chain. Regarding circular stakeholder engagement, the company reflects the three dimensions of Fobbe and Hilletofth. The *Extending* dimension involves broadening the pool of interlocutors beyond corporate boundaries. Pirelli applies this concept by pushing dialogue all the way to the very origin of the supply chain, upstream, where independent natural rubber smallholders in Indonesia are located, as well as engaging the academic and research community (Politecnico di Milano, Università degli Studi di Milano-Bicocca) and non-governmental organizations dedicated to environmental and rights protection (BirdLife International in the area of biodiversity and FSC for forest certification). The *Expanding* dimension addresses the actual scope and content of this dialogue. Engagement is not limited to mere commercial or supply relationships, but broadens to encompass strategic areas such as sustainable product design (Eco-design), the fight against deforestation, and end-to-end raw material traceability. Finally, the company has transitioned from transactional supply relationships to genuine partnerships with opportunities for Joint Development with suppliers and car manufacturers (*Leveling Up*). (Athuraliya, 2024; Fobbe & Hilletofth, 2023; Freeman & McVea, 2001; Pirelli & C. S.p.A., 2025)

Stewardship Theory, on the other hand, describes managers as stewards who handle the pursuit of corporate objectives. At Pirelli, top management

has a very clear vision that has enabled the integration of sustainability into corporate strategy since 2004. In addition, internal remuneration systems based on achieving ESG targets reinforce the fulfillment of the latter. (Donaldson & Davis, 1991; Pirelli & C. S.p.A., 2025; Ungvarsky, 2020)

4.5.2 Circular economy and sustainable manufacturing

Pirelli synthesizes the 9R framework into its own 5R strategy alongside the use of various resource loops. At the level of *Narrowing Loops* (upstream reconfiguration R0–R2), the company relies on Eco-Safety Design and the virtualization of R&D processes through the Virtual Compounder and simulations. This allows reducing the consumption of resources and energy by the vehicle. The cycle of *Slowing Loops* (extending useful life R3–R7) translates into greater tyre mileage and a lower tread wear rate, thereby anticipating the future EURO 7 emissions standard. Finally, closing material loops (*Closing Loops* R8–R9) aims at replacing fossil raw materials with bio-based and recycled ones that are capable of delivering high performance without compromising safety. (Bocken et al., 2016; Brändström & Saidani, 2022; Kirchherr et al., 2017; Pirelli & C. S.p.A., 2025)

The risk of "circular economy babble" (circularity as mere window-dressing) highlighted by Kirchherr et al. and the methodological limitations presented by Brändström and Saidani and Mayer et al. (*burden shifting*) are not obstacles that stop Pirelli. The company commits to introducing LCA across 100% of new product lines (LCA certified ISO 14040/14067 by third parties), thus not limiting itself to the mere calculation of recycled material percentages in its products, but also quantifying the impacts deriving from Carbon, Water, and Biodiversity Footprints. With the addition of new bio-based and recycled materials, the company finds itself required to redesign tyre compounds to avoid losses

in Wet Grip. Pirelli manages all this through balancing strategies, first introducing innovations on top-of-the-range products and only subsequently across the remaining product portfolio to be rolled out to the market. Such a process sometimes requires extensive test cycles lasting over a year, generating substantial R&D costs. A challenge is also posed by the market scarcity of these materials, as Pirelli seeks the highest purity and quality for its premium positioning, resulting in higher procurement costs and supply bottlenecks. (Kirchherr et al., 2017; Pirelli & C. S.p.A., 2025; Taisch & Acerbi, n.d.)

The methodological gap of Social LCA is also highlighted. Literature criticizes the fact that the social dimension is often marginalized within circular economy frameworks (Brändström & Saidani, 2022; Kirchherr et al., 2017; Padilla-Rivera et al., 2020; Taisch & Acerbi, n.d.). The Pirelli case confirms this shortfall while shedding light on its underlying cause: whereas internationally recognized standards exist for the environmental dimension, official methodologies and guidelines are still lacking for Social LCA. Consequently, the company has decided to maintain its cautious stance, grounding its social assessment solely on certified, reported KPIs.

4.5.3 Value creation, cost of capital, and the Resource-Based View (RBV)

Literature examining the intersection between ESG performance and the financial dimension shows that sustainability acts to reduce the weighted average cost of capital (WACC), enhancing expected cash flows. However, a trade-off is often observed regarding the cost of bank debt: while the cost of equity decreases, the cost of debt may increase if lenders perceive environmental expenditures as risky overinvestments. (Gonçalves et al., 2022; Nguyen et al., 2025)

Pirelli's empirical evidence challenges this finding of Nguyen and Gonçalves et al., showing that commitment to sustainability has not

penalized access to credit or sustainable finance instruments. A notable example is the indexing of its core credit facilities to Scope 1, 2, and 3 climate targets: when Pirelli achieves or exceeds the agreed environmental milestones, banks lower borrowing costs by reducing the applied interest margins.

Through the lens of the Resource-Based View (RBV), a firm's competitive advantage does not depend solely on market positioning, but on the development of internal resources characterized by value, rarity, inimitability, and non-substitutability (VRIN criteria). At Pirelli, these attributes find concrete reflection in innovative products. The primary example is the Cyber™ Tyre, an intelligent tyre equipped with sensors that transmit real-time information on vehicle grip and wear. McLaren and Bosch were co-protagonists in the creation of this tyre. (Qiang & Yang, 2023)

Pirelli's competitors often publish high percentages of recycled materials, but these are used only on prototypes (concept tyres) that will therefore not be produced and sold. Pirelli, on the other hand, integrates these solutions into products destined for actual sale. The company does not rely on self-declarations, but relies on certifications issued by independent third-party bodies. This creates a strong barrier to entry that protects the company from the risk of greenwashing, while also helping consolidate its competitive positioning.

4.5.4 EU Taxonomy and disclosure dynamics

Literature regarding sustainability reporting indicates an inherent asynchrony among the three Taxonomy KPIs, particularly in capital-intensive and hard-to-abate manufacturing sectors. (Alessi et al., 2024; Hummel & Bauernhofer, 2024; Rizzato et al., 2026)

Aligned CapEx acts as a forward-looking and predictive lead indicator, whereas Turnover reflects realized revenues generated from the sale of taxonomy-aligned products, thus embodying the physiological lag in market absorption and sales volume adjustment. The evolution of these two indicators within Pirelli provides empirical evidence supporting the theory of lead-lag and transition dynamics of Alessi et al. and Rizzato et al. (Alessi et al., 2024; Rizzato et al., 2026). In 2022, aligned Turnover exceeded aligned CapEx due to pre-existing compliant products in the portfolio and a prudential perimeter mapping of industrial plants. Throughout 2023 and 2024, CapEx grew rapidly to support industrial transition projects. By 2025, convergence occurred between the two metrics: upfront capital investments successfully expanded production capacity, subsequently driving compliant market sales.

Studies by Hummel and Bauernhofer, as well as Koszel, Schmoll, and Jatowt, highlight that many European companies approach taxonomy disclosure and EU regulations primarily as an "endeavour to comply." Such reporting is frequently characterized by uninformative disclosures and near-zero alignment figures resulting from fragmented information systems. (Hummel & Bauernhofer, 2024; Koszel, 2025; Schmoll & Jatowt, 2025)

Pirelli contrasts sharply with this dynamic. The company relies on an integrated information infrastructure connecting Controlling ledgers with R&D product databases on a centralized platform. Consequently, taxonomic indicators are extracted automatically and verified through multi-level validation workflows. Furthermore, Pirelli deliberately excluded Class C Rolling Resistance tyres from its alignment calculations, preventing opportunistic reporting and fictitious KPI inflation.

4.5.5 Supply chain complexity and multi-tier governance

In material-intensive manufacturing industries, Sustainable Supply Chain Management (SSCM) literature identifies opacity across upstream tiers (Tier 2, Tier 3, and Tier 4) as the primary barrier to robust reporting, frequently resulting in degraded data quality. (Akinola et al., 2025; Håbek, 2025; Mageto, 2021)

Pirelli addresses this challenge directly by rejecting reliance on generic sector averages for upstream emissions calculations. Instead, the company collects primary supplier data covering 90% of emissions from strategic raw material suppliers via the CDP Supply Chain program. Pirelli also established early traceability systems for critical natural raw materials. To eliminate deforestation risks and align with the EUDR and CSDDD frameworks, the company implemented third-party FSC® certification for natural rubber and deployed geographic risk analyses in Sumatra utilizing the TNFD LEAP framework.

Nonetheless, empirical findings reveal critical management reflections regarding recent European legislative packages (CSRD, CSDDD, EUDR). Key concerns include excessive administrative bureaucratization and degraded report readability caused by the mandatory PAT (Policies, Actions, Targets) reporting structure, which renders publications accessible almost exclusively to specialized financial analysts and rating agencies. Furthermore, these frameworks generate a competitive disadvantage relative to non-EU manufacturers that do not face equivalent compliance costs running into millions of euros. Initial regulatory proposals seeking to extend strict legal liability indefinitely across every upstream sub-tier were viewed as operationally unfeasible, as attempting full oversight across complex supply chains encompassing thousands of sub-suppliers would create severe legal exposure and structural implementation bottlenecks.

In summary, from this comparison between empirical evidence and the main theoretical models, it emerged that Pirelli goes beyond mere symbolic compliance. The company demonstrates that it has overcome the usual opposition between the maximization of shareholder value (Shareholder Primacy) and the protection of the various stakeholders (Stewardship Theory). This occurred thanks to the link between ESG objectives and strategic capital allocation, incentive systems, and eco-design processes. Furthermore, it was possible to note a contrast, a creation of a trade-off. On the one hand, the development of patented technologies entails a solid competitive advantage based on inimitable resources (RBV); from another point of view, however, recent European frameworks have led to complications in management and an increase in costs to comply with the guidelines along the entire supply chain.

CONCLUSION

The investigation conducted in order to achieve the research results examined the methodological, organizational, and strategic implications linked to the application of the European Taxonomy and of the broader regulatory framework in which it is placed. All this was applied to a single case of a material-intensive manufacturing enterprise such as Pirelli & C. S.p.A.

In response to the first research question (RQ1), it was demonstrated that the company implemented the EU Taxonomy through structured in-house processes, based on the search for an internal methodology and a precautionary approach. Given the absence of a specific category, it had to identify its manufacturing activity within Activity 3.6 (Manufacture of other low carbon technologies) with the objective of Climate Change Mitigation.

As a result to be attributed to the second research question (RQ2), the various organizational, informational, and compliance-related challenges arising from the application of the recent European regulatory framework were identified. Among these are the high bureaucratization of reporting that introduces the PAT scheme leading to the illegibility of the report, the complexity of supply chain Due Diligence (CSDDD and EUDR) requiring upstream traceability (Tier 2, 3, and 4) regarding rubber and chemical components. Furthermore, a competitive disadvantage is created towards non-EU competitors not subject to the same regulations, along with the generation of further increased costs for the procurement of raw materials of very high purity and quality and very long testing periods.

However, management was able to respond promptly to these new directives by implementing various strategic solutions, including the digitalization of R&D and simulations, the introduction of balancing and cascading strategies, the use of certifications from independent third

parties, and supplier and stakeholder engagement programs and the traceability of Scope 3 emissions of strategic raw material suppliers.

Based on the results emerging from the investigation, it is possible to offer advice to other enterprises operating in the manufacturing sector and grappling with the ecological transition.

Area of Intervention	Managerial Recommendation and Strategic Action	Expected Organisational and Competitive Benefit
Data Architecture and IT Systems	Integrate ESG data collection and KPI calculation directly into corporate ERP/SAP systems (Single Source of Truth).	Elimination of accounting errors, full data auditability (XBRL digital tagging), and automated KPI calculation.
Cross-Functional Governance	Establish permanent coordination committees between Sustainability, Finance, R&D, Operations, and Risk Management under Board supervision.	Alignment between capital investments and climate targets, with integration of ESG metrics into incentive systems (STI/LTI).
Supply Chain Management	Evolve supply chain relationships toward capacity building models, Joint Development contracts, and direct tracking of raw material suppliers.	Transparency on Scope 3 data, proactive compliance with CSDDD/EUDR regulations, and security of supply for critical raw materials.
Product Planning (Balancing Strategy)	Implement a phased introduction of sustainable materials on high-margin flagship products, progressively cascading them to mass production.	Operating margin protection, absorption of R&D testing costs, and progressive expansion of product range efficiency.
Certification Policy	Subject environmental claims, procurement management, and raw material origins to independent third-party verification (ISO 14021, ISO 20400, FSC®).	Protection against greenwashing risks/litigation and creation of reputational and competitive barriers against peers.
Sustainable Finance and Capital	Link decarbonisation targets and EU Taxonomy metrics to bank credit facilities and bond issuances (Sustainability-Linked instruments).	Direct reduction in the cost of debt (favourable interest rate step-downs) and expansion of the institutional investor base.

Source: B. Binda (2026)

The analysis carried out, however, presents some structural limitations to highlight. The first to stand out is the limitation of the single case study, as the investigation is concentrated on a single multinational enterprise. Although an in-depth analysis is offered, the results cannot be generalized to the entire manufacturing sector. Furthermore, Pirelli is positioned in the High Value segment where margins are high and there are direct

collaborations with Premium and Prestige car manufacturers, while manufacturing companies operating in the mass market could have difficulties adopting the same strategy as Pirelli due to the high costs that this entails.

Another limitation concerns the evolution of the regulatory framework; this research refers to the 2021–2025 period, which means that with the publication of new regulations or amendments by European institutions, reporting requirements could change.

In light of the reported evidence and limitations, various insights for future research are offered. The analysis can be broadened through comparative research that includes companies in the Tyre & Rubber and automotive sectors at a global level, thus comparing European companies subject to the EU Taxonomy with non-EU companies.

Another insight concerns the development of long-term quantitative models measuring the conversion rate and lag times between industrial investments in aligned CapEx and commercial return in terms of aligned Turnover.

The in-depth analysis concerning the development of standardized frameworks to measure the social dimension (Social Life Cycle Assessment) constitutes another research element. In this way, it will be possible to understand how to overcome fragmentation and integrate the assessment of human rights along the value chain.

Finally, an analysis could be conducted regarding the impact of the announced European revisions on corporate administrative burdens. It could be assessed whether a possible reduction in the required bureaucracy alters or not the effectiveness of the Taxonomy in steering financial markets.

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