UNIVERSITÀ DEGLI STUDI DI PADOVA

DIPARTIMENTO DI SCIENZE CHIMICHE

CORSO DI LAUREA IN SUSTAINABLE CHEMISTRY AND TECHNOLOGIES FOR CIRCULAR ECONOMY

Drafting Corporate Sustainability Reports: analizing technical and social practices and impacts of companies

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ANNO ACCADEMICO 2024/2025

Acknowledgements

I would like to thank my classmates, with whom I shared not only an academic journey but also moments of growth and exchange.
A heartfelt thanks to my professors, who did not merely pass on knowledge but inspired me with their passion.
A special thank you goes to my family, who supported me with strength and love every day, believing in me even when I struggled to do so myself.

Abstract
This thesis analyzes the transition from the Linear Economy to the Circular Economy, with a particular focus on the implementation of sustainability in small and medium-sized enterprises, the largest source of industrial pollution in Europe. After examining the impact of the linear economic model, the need to adopt sustainable strategies to ensure long-term sustainability is highlighted.
Through the case study of a metalworking company, a Sustainability Report based on GRI Standards was prepared, outlining a roadmap for reducing environmental impact and integrating more sustainable production practices. Particular attention was paid to optimizing the company's production processes by adopting alternative technologies to flood cooling, such as minimum quantity lubrication and dry cutting, which reduce coolant consumption and improve operational efficiency. The analysis performed highlighted both the critical issues and opportunities of these innovations, assessing their economic, environmental and social impacts.
An analysis was also conducted on the use of paper in the company, emphasising the importance of digitalisation to promote more efficient communication along the entire production chain and to improve interaction with stakeholders. At the same time, the use of company packaging was evaluated, identifying possible solutions to make it more sustainable.
The energy analysis conducted identified the main sources of consumption and the related CO_2 emissions, leading to the definition of strategies for corporate decarbonisation. Among the proposed solutions, heat recovery from the compressor and the adoption of electric heat pumps make it possible to eliminate the use of natural gas, while the replacement of diesel vehicles with an electric car eliminates direct emissions from the fleet. The optimisation of energy consumption is supported by targeted interventions, such as the replacement of fluorescent lamps with high-efficiency LEDs and the implementation of a Building Automation and Control System for intelligent energy management. Finally, it is proposed to maximise the self-consumption of the company's photovoltaic system and to ensure the supply of certified renewable energy through Guarantees of Origin (GO). The results show that the integration of circular economy strategies not only significantly reduce CO_2 emissions and resource consumption, but also help to improve corporate

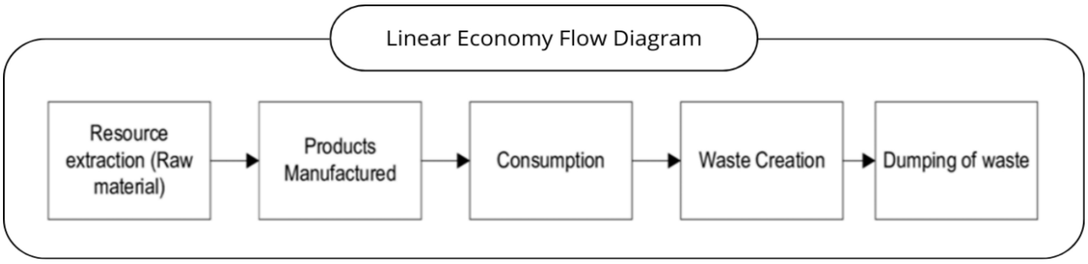
competitiveness, promoting a sustainable development model. This approach is aligned both with new European regulations and with an evolving market that is increasingly oriented towards a balance between profit, environmental protection and social responsibility.

Summary

1.0 Linear Economy

The idea that raw materials and energy resources, and therefore all consumer products, are inexhaustible, has taken root and grown in society throughout history, particularly since the Industrial Revolution. This belief fuelled the illusion that nature could satisfy every human need, while industry only had to adapt to market demand. This paradigm drove the development of the economy towards a linear model, based on the false assumption of the infinity of the planet's resources, and laid the foundation for the new market system based on consumerism. The Linear Economy model is based on a continuous flow of resource extraction and consumption, without any cyclical process. Specifically, the creation of any product involves five basic stages, reporting on the follow flow diagram:

Figura 1: Linear Economy Flow Diagram[1]



This model, known as "take-make-dispose", involves the continuous extraction of natural resources to produce finished goods for consumption, and this system has led to the annual extraction of 100 billion tonnes of raw materials. The extraction of raw materials is not only seen as a cost, but also a as a source of significant environmental damage. According to Ancler, a platform that monitors pollution, a new study reveals that greenhouse gas emissions from mining and resource extraction worldwide cause $3 billion worth of damage each year. Additionally, the average consumption of energy and water required to produce critical raw materials from minerals exacerbates the environmental impact. The table below examines the difference in terms of environmental impact between the extraction of raw materials from minerals and those from processing waste.

[1] https://www.researchgate.net/figure/Linear-economy-flow-diagram_fig1_336243057

Figura 2: A comparison between scrap and ores, water consumption and energy consumption[2]

Water and Energy Consumption for Scrap vs Ores

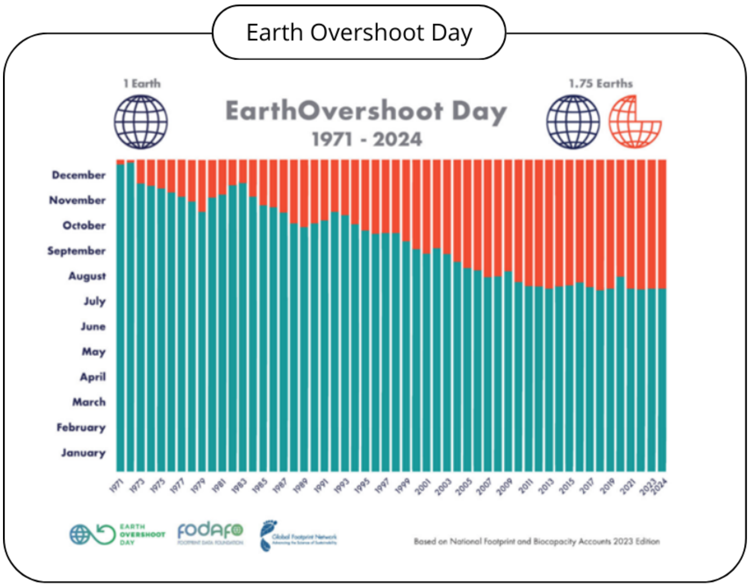
Metals	Energy use in metal extraction, MJ/kg		Water use, m^3/t	
	Scrap	Ores	Scrap	Ores
Mg	10	197.5	2	8.5
Al	10	580	2	165.5
Cu	14	1,035	15	120
Sn	15	1,330	5	102.5
Ni	20	250	20	190
Co	80	1,120	65	1,020
Ag	130	2,380	30	130
Au	185	32,800	30	270,000
PGM	2,400	136,680	4,500	650,000
REE	3,000	6,350	750	1,540

For much of the 20th century, the linear approach to economics was based on the production of goods and services at the lowest cost. Raw materials are extracted from nature at the lowest cost, processed into products using the least amount of labour, and sold at the highest price. The Linear Economy has had significant undesirable effects, including two main irreversible consequences. Firstly, there is an increasing demand for raw materials and energy, without taking into account their finite nature and the limits imposed by the environment. Secondly, there are the pollution problems associated with the production and disposal of waste from finished products. An example is the global reserves of certain metals essential for the production of batteries and electronic devices, which will be exhausted in a relatively short time if they are not recycled. In particular, reserves of lithium (Li) will be exhausted in about 250 years. Reserves of nickel (Ni), used extensively in batteries and metal alloys, will be depleted in just 38 years, a critical issue for the sustainability of current technologies. Cobalt (Co), essential for the production of rechargeable batteries, will also be depleted

[2] Gross S., (2024). *From the Critical Raw Materials Act to the Battery Regulation: New Challenges for the European Circular Economy and Circular Chemistry Landscape, Summer School on Corporate Sustainability.*

in 52 years if mining and consumption trends do not change[3]. Analysis of this data highlights the urgency of developing effective and sustainable recycling strategies to conserve these resources and ensure the continuity of future technologies. With regard to the first aspect, it is reported the evolution of Earth Overshoot Day, an index calculated by the Global Footprint Network that indicates the date at which human demand for resources exceeds what the planet can produce in a given year. This value is derived from the ratio of the planet's biocapacity (the amount of all the resources the Earth that can produce each year, “BIO”), to humanity's Ecological Footprint (the total demand on resources for the entire year, “HEF”), multiplied by the number of days in a year.

Figura 3: Earth Overshoot Day, 1971-2024[4]



$$EOD = BIO/HEF \times 365$$

As can be seen from the image, the date of Earth Overshoot Day has been gradually decreasing over the years. On 1 August 2024, human consumption will have exceeded the planet's regenerative capacity in 2024, creating an ecological deficit, a natural debt to the future.

The second issue concerns the generation of processing waste, greenhouse gas emissions, grey water discharges and waste throughout the production chain. These not only have a significant impact on the ecosystem, but also lead to a loss of value along the entire supply chain. One of the main consequences is greenhouse gas

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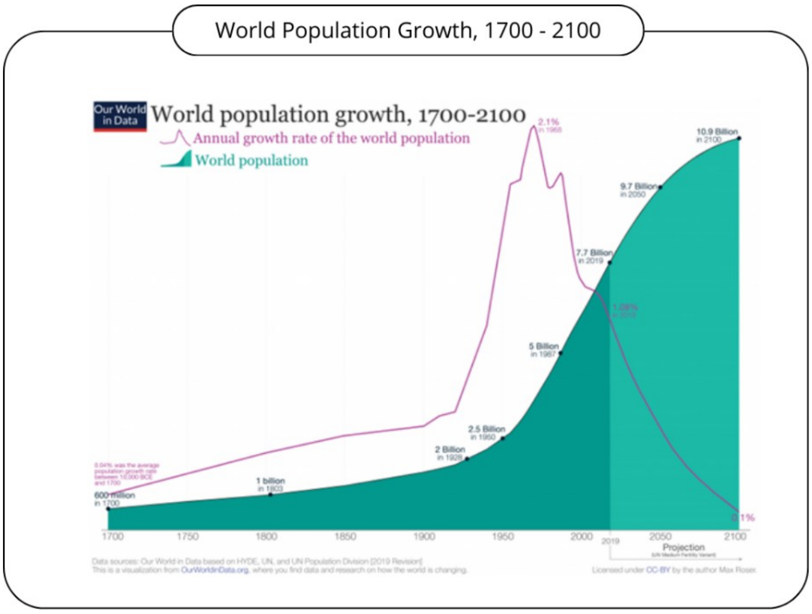
[3] Fantin M., (2024). *Biorefineries and sustainable energy production and storage for circular economy, lecture 5.8: Li Battery recycling. University of Padua*

[4] https://www.footprintnetwork.org/our-work/earth-overshoot-day/ [consulted on September 11th, 2024]

emissions, which contribute to climate change by trapping heat from the sun in the atmosphere, causing irreversible damage to the planet. One of the most significant impacts in Europe is flash floods caused by localised heavy rainfall events. The acceleration of the hydrological cycle has serious implications, particularly in terms of forecasting and adaptation. This increase in precipitation intensity is largely due to human activities. CO_2 emissions, which have exceeded the critical threshold of 400 ppm, are warming the lower atmosphere and causing temperatures to rise. According to the Clausius-Clapeyron equation, each degree Celsius increase in temperature leads to a 7% increase in the amount of water vapour retained in the atmosphere. This phenomenon not only drastically alters the hydrological cycle, but also has a major impact on the availability of drinking water resources.[5]

1.1 Linear Economy Implications

Figura 4: World population growth, 1700-2100[6]



Materials that are discarded without being recovered can be found in every sector and at every stage of the value chain, not just after final consumption. With the world's population predicted to grow to nearly 11 billion by 2100, it is clear that minimising human impact on the environment is essential to avoid irreversible damage to the planet and ensure a sustainable ecosystem for future generations.

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[5] Zuecco G, (2023)., *Water resources management in the circular economy, lecture: Climate Change and Natural Disasters (flood and droughts) University of Padua.*

[6] https://www.youtrend.it/2022/04/29/il-futuro-della-crescita-della-popolazione-mondiale/ [consulted on September 11th, 2024]

The growing problem of waste is not only influenced by the population growth, but also by the short lifespan of products. Everyday items, such as packaging, often have a short life cycle and contribute to the daily accumulation of waste.
In particular, two categories of products can be distinguished on the basis of their life cycle:

- Fast moving consumer goods: goods that are purchased frequently and consumed quickly, with a short life cycle. They are available on the market at large quantity and at low cost and therefore do not require a difficult purchase decision by the end consumer.
- Durable goods: goods that have a long useful life and are not consumed immediately after purchase, common examples include household appliances or cars. The purchase of such a product has a high cost and therefore requires more decision making on the part of the consumer.

As a result, companies that produce durable goods can be affected by the extended life cycles of their products, exposing them to competition and to a possible slowdown in sales over time.
What follows, is a detailed analysis of the market and the choices that some companies operating in the durable goods sector have made over a long period of time and that still affect product life cycles today. Starting from the Cartesian plane, with the quantity of goods sold on the x-axis and the selling price on the y-axis, the examination of monopoly situation is presented, in which monopolist is the price-maker and has the control over selling price.

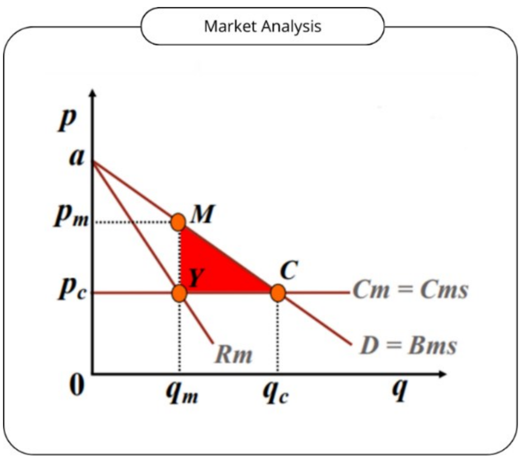


Figura 5: Market Analysis[7]

The graph shows the market demand curve for a good D=Bms, which, as can be seen, is downward sloping, indicating that as the quantity demanded increases, the price decreases. The marginal revenue curve Rm, on the other hand, represents the additional

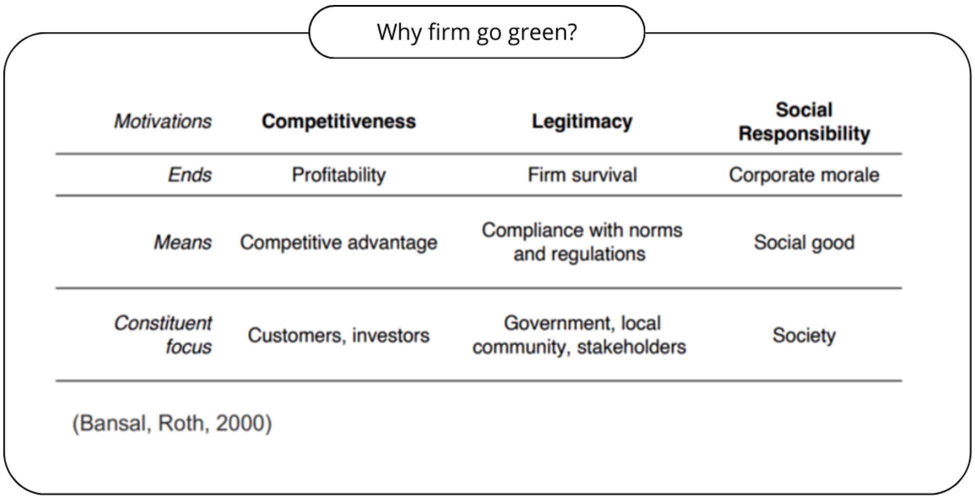
[7] Lorenzoni A. (2024). *Sustainability Strategies and Energy Economics, University of Padua*

revenue that a monopolist receives by selling one more unit of good. This value is always below the demand curve because, in order to sell additional quantities, the monopolist must reduce the price to all consumers. The marginal cost curve Cm=Cms represents the additional cost of producing one more unit of the good. On the graph, this curve is a horizontal line, indicating that marginal cost is constant for the quantities produced. The monopoly equilibrium point, denoted by M, is the point at which the monopolist produces a quantity qm at the corresponding price pm. As can be seen from the graph, in a monopoly situation the price is higher than marginal cost and there is a loss of social welfare. On the other hand, point C represents the situation of perfect competition, where the price pc is equal to marginal cost and the quantity produced qc. An important element of the graph is the social welfare loss triangle, represented by the area between points C, M and Y. This area highlights the social efficiency loss due to monopolistic behaviour. As can be seen, residual demand extends beyond qm along the demand curve. This gives the monopolist the opportunity to sell additional quantities, but on the condition that the price is progressively reduced over time. The result is a new equilibrium point C, where the price is lower than before. In the long term, it is advantageous to lower the price in order to sell the product to those consumers who have not yet bought it, allowing the monopolist to obtain a surplus that it could not be obtained by keeping the price high. This phenomenon is known as 'inter-temporal price discrimination', which consists of lowering the price over time, to encourage further sales. Moreover, in order to satisfy total market demand, the monopolist will eventually have to sell the good at a price equal to the marginal cost of producing one unit, as in the case of perfect competition. This is known as the Coase conjecture. It suggests that, in the case of durable goods, if consumers are rational and their opportunity costs are low, they will tend to postpone their purchases until the price falls to the cost of production. This is because the ability of consumers to postpone purchases negates the market power of the monopolist. To deal with the problem of durable goods, companies adopt a common practice known as 'planned obsolescence'. This strategy consists of deliberately reducing the lifespan of products on the market by imposing a relatively short period of use. The aim is to force consumers to replace their goods frequently, thus keeping consumer demand 'artificially' high. Once this period has expired, the product starts to show defects or failures, forcing the consumer to bear the cost of maintenance or to replace it with a newer model. At the same time, new models with seemingly improved technical features are introduced, making the previous product seem obsolete, even though its performance is not necessarily inferior. Planned obsolescence practices still in use today have two main problems. Firstly, they penalise consumers by forcing them to replace durable goods with new ones on a regular basis, leading to unnecessary expenditure. Secondly, these strategies assume an unlimited availability of resources and ignore the negative environmental consequences of avoidable continuous consumption, which leads to the accumulation of waste. In order to discourage this marketing strategy, the Green Claims Directive (EU) 2024/825 has been proposed, which not only highlights a number of problematic marketing strategies related to greenwashing, i.e. misleading claims made by companies to promote the environmental benefits of their products and services, but also the problem of premature obsolescence of goods. These will be added to the EU's list of prohibited business practices and EU member states will have until 27 March 2026 to transpose them into national law. This Directive shows how Europe is moving towards sustainability, promoting strategic initiatives that help to meet the needs of the present without compromising the ability of future generations to meet theirs. The concept of consumption should be rethought on the basis of natural principles: just as in nature nothing becomes waste, but rather food for other organisms, so industry should imitate nature and transform the concept of waste into a resource. It is the social duty of society, and therefore also of companies, to pursue a virtuous cycle of production that takes into account not only profit but also social conditions and respect for the environment.

2.0 The transition to green and the problems of SME

In recent years, the paradigm shift from Linear to Circular Economy has been the focus of many ethical, scientific and legal studies. Gradually, the ESG concept is becoming part of everyday life, and even companies are trying to integrate this paradigm into their core business. This shift is done not only to comply with regulations, that increasingly require them to provide information and adopt sustainable practices, but also to stay in the market, as the adoption of sustainable techniques increases not only the value of products and services, but also long-term competitiveness. As Professor Alan Palmiter denoted, the majority of investors take ESG into account, with 89% recognising its importance. This suggests that ESG considerations have become a mainstream expectation rather than a niche preference, and that the adoption of these principles is seen as essential in modern society for risk management, reputation and alignment with stakeholder values.[8]

Figura 6: Why firm go green[9]



Why firm go green?

Motivations	**Competitiveness**	**Legitimacy**	**Social Responsibility**
Ends	Profitability	Firm survival	Corporate morale
Means	Competitive advantage	Compliance with norms and regulations	Social good
Constituent focus	Customers, investors	Government, local community, stakeholders	Society

(Bansal, Roth, 2000)

The main reasons why a company moves to the new paradigm are:

- Competitiveness: many competitors are investing in the sustainability dimension.

[8] Palmiter A., (2024). *Awaking Capitalism, Summer School on Corporate Sustainability.*
[9] Di Maria E., (2024). ESG, *Environmental Strategies and Firm Competitiveness, Summer School on Corporate Sustainability.*

- Legitimacy: the main goal for companies is survival (and therefore profit). Now the goal is for the company to be sustainable over time, taking into account not only customers and investors, but also local community (and all other stakeholders).
- Social Responsibility: when producing something, organizations must always consider the impact that the product will have on the local community and the ethical, environmental and social consequences associated with it.[10]

Small and medium-sized enterprises are defined by the European Commission as companies with fewer than 250 employees and an annual turnover not exceeding €50 million or an annual balance sheet total not exceeding €43 million. This definition highlights the diversity of SMEs, ranging from micro-enterprises with a few employees to medium-sized enterprises operating in highly specialised sectors. In the European Union, SMEs are a key pillar of the economy, accounting for 99.7% of all enterprises in the European Union.[11] They provide 2/3 of private sector jobs and generate around 56% of EU GDP, demonstrating their central role in creating economic value and supporting overall economic growth.[12] However, despite their positive economic impact, SMEs contribute significantly to pollution: it is estimated that these companies are responsible for around 70% of industrial pollution in Europe.[13] These datas reflect one of the biggest challenges facing SMEs: the ability to implement sustainable practices to reduce their environmental impact. In sectors such as manufacturing, agriculture and construction, their contribution to pollution is a significant problem, especially as traditional practices have a linear relationship with the generation of waste and emissions. SMEs are different from large companies not only because of their size, but also because they have to compete with many competitors in the same business environment. At the same time, they are always in a race against time: the day-to-day running of the business is so intense that they have

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[10] Di Maria E., (2024) ESG, *Environmental Strategies and Firm Competitiveness, Summer School on Corporate Sustainability.*

[11] https://eur-lex.europa.eu/IT/legal-content/glossary/small-and-medium-sized-enterprises.html#:~:text=un'impresa%20di%20piccole%20dimensioni,a%202%20milioni%20di%20euro [consulted on June 18th, 2024]

[12] https://www.sdabocconi.it/it/sda-bocconi-insight/cantieri-di-ricerca/sostenibilita/il-valore-della-sostenibilita-per-le-pmi [consulted September 26th, 2024]

[13] https://www.agi.it/innovazione/news/2022-04-22/pmi-pesano-70-per-cento-inquinamento-industriale-16456979/ [consulted on August 23rd, 2024]

to devote all their resources to it, trying to remain profitable in order to survive. Implementing sustainable practices requires a commitment of additional time and resources that many SMEs may struggle to find. While large companies can afford teams dedicated to sustainability, SMEs are often run by small teams juggling multiple responsibilities. Another problem that SMEs face on a daily basis is low profit margins and consequently limited cash flow, a limiting factor when it comes to investing in sustainable solutions that require large initial investments in Research and Development, the purchase of more efficient equipment and materials, and staff training. It is very common for SMEs with limited financial resources, when evaluating an investment, to favour investments that guarantee a more immediate return, thus hindering progress towards sustainability. This risk aversion, which leads SMEs not to invest in sustainability, means that they miss out on long-term competitive advantages, an enhanced corporate reputation and new future markets. Overcoming this barrier is essential if these companies want to take full advantage of the opportunities offered by sustainability and lay a solid foundation for future growth.[14] The central figure who can help to overcome this barrier and promote a culture of sustainability within the company is the owner. In many SMEs, the manager is often the founder or owner of the organization, which means that the opinions of this person, the personal beliefs and attitude to risk, have a direct influence on all business decisions. This means that, on the one hand, if the manager has a positive view of sustainability and recognises the long-term benefits of the Circular Economy, he can easily steer the company towards adopting such practices. On the other hand, a strong risk aversion, which is common among many SME owners, can be an obstacle to their adoption, despite the potential environmental and economic benefits. The corporate culture of SMEs is therefore a powerful driver of change needed to effectively address environmental challenges and remain competitive in an increasingly sustainable economy.[15] It is also essential that SMEs receive more support, both in terms of access to finance and technical and training assistance. This support is crucial not only for the success of individual

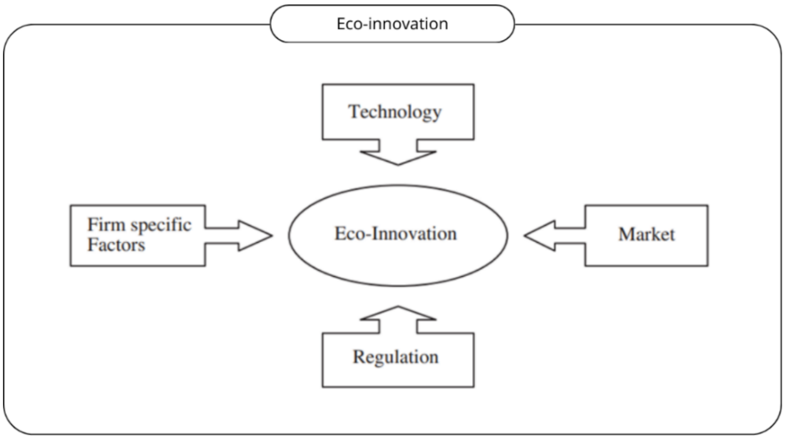
[14] https://www.altrafinanza.it/2024/03/05/strategie-per-ottimizzare-i-flussi-di-cassa-nelle-pmi/ [consulted on September 3rd, 2024]
[15] Freixanet J. et al. (2020), *Managerial Risk Attitudes and the Adoption of Green Innovations*, *Journal of Small Business Management*, Vol. 58, Issue 4.

companies, but also to ensure that the SME sector continues to make a positive contribution to the European economy while reducing its environmental impact.

2.1 Ecoinnovation

In recent years, numerous studies have been carried out to identify the determinants of eco-innovation. Several factors can act as catalysts for eco-innovation in SMEs, and these drivers have been grouped into four main clusters:

Figura 7: Ecoinnovation[16]



- Market-pull (expected economic performance, demand for green products, consumer preferences);
- Technology-push (firm knowledge assets, R&D investment, organisational capabilities and innovation);
- Regulation (impact of policy incentives);
- Firm-specific factors (age, size, position or sector of the firm).

The first cluster to be analysed is the Market Pull one. This cluster combines market pressures and opportunities that drive companies to adopt sustainable strategies. This propensity comes not only from regulation, but also from the market itself, driven by expected economic performance: companies recognise that the adoption of sustainable practices is not just a regulatory or ethical issue, but also brings concrete economic benefits, leading to greater operational efficiency. As these improvements are adopted, new markets that value sustainable products are opened up, creating long-term value. At the same time, the growing focus on environmental dynamics has led to an

[16] Horbach J., Rammer C. and Rennings K (2012). *Determinants of eco innovations by type of environmental impact — The role of regulatory push/pull, technology push and market pull.*

increased of demand for green products from consumers, who are willing to reward companies that offer verified sustainable products and services with their loyalty. This was highlighted in a study conducted in Italy, where 80 % of consumers said they were very concerned about sustainability.[17] For small and medium-sized enterprises (SMEs), responding to this growing demand is an opportunity to differentiate and stand out from the competition, attract a wider customer base, gain a sustainable competitive advantage and build a positive long-term image.

The second cluster analysed is the Technology Push one, which shows that innovation is not only a response to external pressure but also is related to the knowledge of the firm. The focus of this cluster is on the inside of the company, as it is the factors within the company that most influence its ability to develop and implement technological innovations. Companies with continuous training and solid technical skills are more likely to develop innovative solutions. Training therefore builds not only organisational capacity, but also the willingness to review and adapt business and management models to fully integrate sustainability into all business activities.

The Regulation cluster analyses the role of regulation and public policy in the uptake of environmental innovations. The difficulties faced by SMEs are widely recognised by public authorities, and economic support measures are often provided to facilitate this transition. Incentives are the tools that can reduce the upfront costs of implementing environmental innovations. The role of regulations not only make sustainable technologies more accessible, but can also accelerate their uptake by SMEs, thus facilitating wider and faster adoption. An example of this, is the Transition Plan 5.0, in which the Italian government has included a strategy to support the digital and energy transformation of companies, with €12.7 billion available in 2024-2025.[18] The development of SMEs includes not only the pressure of current, but also future regulations, allowing companies to be perceived by society as leaders in the field of sustainability, improving their reputation in the market.

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[17] https://www.confindustria.it/home/notizie/SOSTENIBILITA-CONFINDUSTRIA-CONSUMATORI-GUIDATI-DA-QUALITA-E-PREZZO-L-80-SI-DICHIARA-ATTENTO [consulted on June 24th, 2024]

[18] Outlined in the recent law of conversion of the decree law on the implementation of the PNRR, law 29 April 2024, n.56

The Firm-Specific factors cluster examines the unique intrinsic characteristics of a firm that influence its ability to adopt environmental innovations. The factors that most influence SMEs in adopting sustainable practices include four main elements: the age of the company, its size, its geographical location and the sector in which the organization operates. Younger companies are generally more open to new developments. They are not yet tied to old habits that are difficult to change and are therefore more likely to adopt sustainable technologies and practices at the earliest stages of their development. However, this innovative sprint can be hampered by a lack of experience and the financial resources needed to implement these new ideas. On the other hand, more mature companies often have easier access to resources and skills, but may find it harder to change. In terms of size, as mentioned above, SMEs often have fewer resources than large companies, which can make it more difficult for them to access cutting-edge environmental technologies. On the other hand, SMEs are flexible in their decision-making, which means that they can adapt to market changes and adopt new practices more quickly than large organisations, which may be slower and more bureaucratic. Geographical location is also important. If a company is located in an area where the government or local authorities provide incentives and support for green initiatives, it is easier for the company to take advantage of these opportunities and move towards sustainability. In areas where this support is lacking, the transition becomes more complicated. Industrial sectors are also important: in some, failure to adopt sustainable practices risks falling behind the competition, while in more traditional sectors such as heavy industry or chemicals, the complexity of the processes and the high cost of the new technologies required to make it much more difficult to adopt green practices.[19]

Environmental Innovation (EI) in SMEs, as just discussed, has some specific features that distinguish it from traditional innovation. The concept of "Double Externality" is introduced to explain the complex dynamics that characterise EI. The double externality refers to two types of impacts that these innovations can have on the market and society. First, there are positive externalities. These arise when environmental

[19] Horbach J., Rammer C. and Rennings K (2012). *Determinants of eco innovations by type of environmental impact — The role of regulatory push/pull, technology push and market pull.*

innovations generate benefits beyond the firm that developed them, creating a chain effect that benefits other economic actors. A typical example is knowledge spillovers, where the diffusion of innovative technologies or best practices enables other companies and sectors to use these innovations without incurring research and development costs. In other words, the knowledge and technologies created by one firm spread through the economy, generating collective benefits without the original firm being able to reap all the economic benefits from its investment. On the other hand, there are negative externalities, which are directly related to the primary objective of environmental innovations: reducing harmful effects on the environment. These innovations contribute to improve the quality of the environment, while at the same time generating benefits for society as a whole. In the meantime, the costs of developing and implementing these technologies are borne mainly by companies, which sometimes do not pass on the full costs to consumers or other stakeholders. This dual nature of externalities leads to a "double market failure". On the one hand, positive externalities mean that firms cannot fully capture the economic benefits of their innovations because a significant proportion of these benefits is passed on to other firms and society for free. On the other hand, although negative externalities reduce environmental damage, the costs of adopting such innovations are borne almost entirely by firms, which may be discouraged from investing in such projects because of insufficient returns[20]. This gives rise to a new problem that modern society is trying to address, the spread of greenwashing. This phenomenon, fuelled by the lack of standardised ESG metrics, is what Professor A. Palmiter calls “Dark Cloud”. The Dark Cloud is defined as behaviours or activities that give the impression that the company is doing more to protect the environment than it actually is, thereby artificially influencing the final consumer's choice when purchasing a given product. The prevalence of this practice is reflected in the 2020 analysis, where the EU executive found that at least 53.3% of the environmental and climate claims made on the labels of a large sample of products were misleading and 40% was completely unfounded.

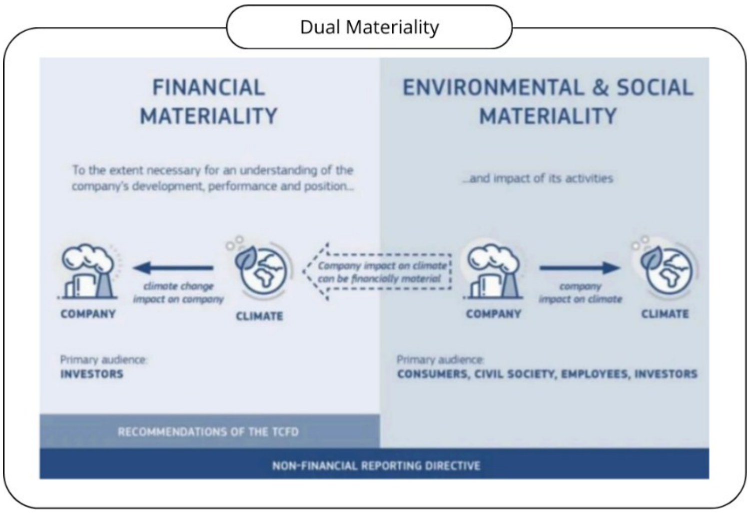
[20] https://iris.unibs.it/retrieve/bc7d3462-b6eb-44d6-bb95-f23863d8de8e/FP%20-%20Clean%20version.doc%20-%20Documenti%20Google.pdf [consulted on July 22nd, 2024]

2.2 SME development and the role of CSRD

To overcome not only the double market failure, but all its consequences connected, it is essential that companies are reliable to investors and at the same time actively communicate their actions transparently. Hence the need for effective public intervention. On 10 September 2024, the Italian Official Gazette published Legislative Decree No. 125/2024 transposing EU Directive 2022/2464, known as the Corporate Sustainability Reporting Directive (CSRD). It sets the framework for the preparation of sustainability information to be included in the Sustainability Report. Many academics believe that the implementation of the CSRD will reduce distortions of competition caused by greenwashing and misleading information in product marketing, emphasising the principle of transparency, the cornerstone of current EU policy. Specifically with the CSRD, the European Commission is imposing new and stricter rules on Sustainability Reporting, replacing and extending previous directives such as the Non-Financial Reporting Directive (NFRD). From January 2024, reporting entities already subjected to the NFRD will have to report in 2025 on the 2024 data. From January 2025, all large reporting entities not currently subject to the NFRD will have to report in 2026 on 2025 data and from January 2026, all listed SMEs, small and non-complex credit institutions and captive insurance companies will have to report in 2027 on the 2026 data. Significantly, the CSRD is not only relevant in Europe, but also extraterritorial, meaning that non-EU companies generating more than €150 million in the EU market will also be required to report on their social and environmental sustainability. This Directive therefore introduces the responsibility of the company for the sustainability of its supply chain, including the principle that companies are responsible for the overall CO_2 emissions impact of their supply chain and the measures taken to identify and monitor this impact. This means that companies' purchasing behaviour will change, favouring purchases from companies with lowest environmental and social impact, even at the expense of economic convenience.[21]

[21] Lavagnolo M. C., (2024). *Environmental Engineering Supporting the ESG to Avoid Greenwashing, Summer School on Corporate Sustainability.*

Figura 8: Dual Materiality[22]



The CSRD introduces the concept of Dual Materiality, which includes two materialities: the Impact one and the Financial one. Financial Materiality refers to the way in which sustainability issues affect a company's financial performance, while Impact Materiality refers to the potential negative impacts of the company's activities on society and/or the environment. Based on the concept of Dual Materiality, companies must be accountable for both the sustainability issues and the financial impacts of all their activities, reflecting the intention of European legislators to monitor the impact of companies on society and environment. [23]

The Sustainability Report is the key management tool for decision support and internal and external communication of the value created. The aim is to provide investors and stakeholders with more detailed, clear, standardised and comprehensive information on sustainability, to drive customers into more conscius choices. Specifically, if companies are required to produce a Report, the document is called a Non-Financial Disclosure, if they produce it voluntarily, it is called a Sustainability Report.[24]

[22] *European Accounting Association; Proposal for a Corporate Sustainability Reporting Directive*

[23] Shurr, (2024). *The Implementation of the CSRD – Risks and Opportunities for Companies, Shareholders, and Stakeholders, Summer School on Corporate Sustainability.*

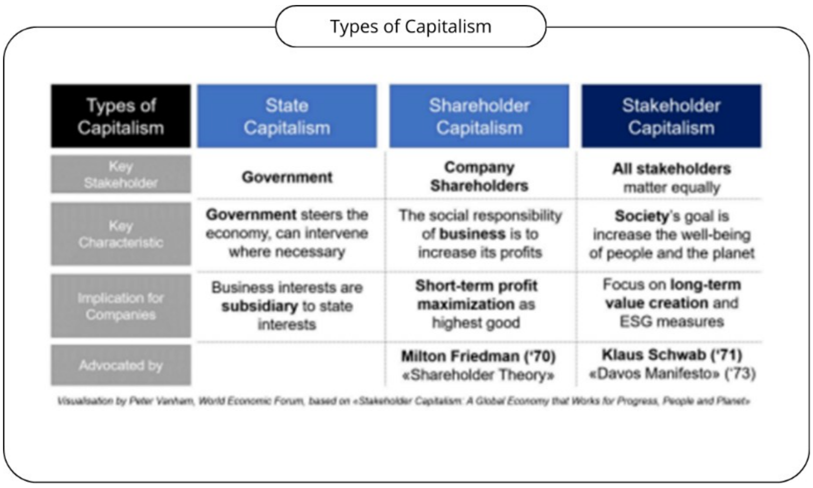
[24] Lavagnolo M. C., (2024). *Environmental Engineering Supporting the ESG to Avoid Greenwashing, Summer School on Corporate Sustainability.*

3.0 The adoption of a corporate strategy

The strategy plays a key role for the company, as it allows to translate into concrete action the theoretical objectives previously defined. Once the purpose is clear, the company must establish how to achieve it, planning a long-term strategy that analyses not only what it does for society but also the impact that its product has on society. The strategy not only defines the objectives that the company intends to achieve, but also indicates the methods for achieving them, taking into account the competitive space surrounding the organization. The concept that is maturing in the last decades is that when a company creates value, it must go beyond maximum profit. Hence, the definition of Purpose as: "The purpose is the statement of a company's moral response to its broadly defined responsibilities"[25] "... with the aim of defining the scope and extent of business activity to promote the well-being of society and individuals within and outside the company"[26].

Using an approach that not only creates profit but also considers the social and environmental dimensions is dictating the foundations for a new form of capitalism that takes stakeholders into account.[27]

Figura 9: Types of capitalism


Types of Capitalism

Types of Capitalism	State Capitalism	Shareholder Capitalism	Stakeholder Capitalism
Key Stakeholder	**Government**	**Company Shareholders**	**All stakeholders** matter equally
Key Characteristic	**Government** steers the economy, can intervene where necessary	The social responsibility of **business** is to increase its profits	**Society**'s goal is increase the well-being of people and the planet
Implication for Companies	Business interests are **subsidiary** to state interests	**Short-term profit maximization** as highest good	Focus on **long-term value creation** and ESG measures
Advocated by		**Milton Friedman ('70)** «Shareholder Theory»	**Klaus Schwab ('71)** «Davos Manifesto» ('73)

Visualisation by Peter Vanham, World Economic Forum, based on «Stakeholder Capitalism: A Global Economy that Works for Progress, People and Planet»

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[25] Bartlett C. A. and Ghoshal S. (1994). *Havard Business Review.*

[26] Hollensbe et al. (2014). *Academy of Management Journal.*

[27] Di Maria E., (2024) ESG, *Environmental Strategies and Firm Competitiveness, Summer School on Corporate Sustainability.*

To be effective, a strategy must take into account a wide range of factors, including political, economic, social, technological, environmental and legal issues, as well as the opportunities and challenges related. The company also needs to reflect on itself and assess its own resources and capabilities, i.e. what it is good at. The new Business Models have led to a shift in focus from shareholders to stakeholders and to a change in internal objectives: if in the past the economic aspect was paramount, today the company's reputation has become more important. From this, we can deduce the strategic importance of stakeholders, which in turn influences the company's reputation. It is well known that 91% of Generation Z are willing to pay 10% more for a sustainable product.[28] This change highlights that the economic aspect is no longer the only priority, but that the environmental and social impact of the company has become an extremely important element at the point of the choice of purchase. A 'green' reputation has become essential not only for companies, but throughout the supply chain, so that long-term suppliers are often selected by companies on the basis of their environmental impact. The new Business Model is known as "PaaS" (Product as a Service) and represents a major shift in the traditional ownership paradigm. In this model, ownership of the product is not transferred to the end customer, but remains under the control of the company. It offers goods as part of an ongoing service, rather than through a single sale, allowing products to be designed from the outset with end-of-life recycling in mind, reducing costs and creating new value. In this model, customers become co-creators of value with the company and the product is no longer the end, but the means by which a service is delivered. Maintenance and repair costs remain with the company, encouraging the design of more durable and reliable products. This not only extends the useful life of goods, but also encourages more sustainable consumer behaviour by reducing the need to replace products before they are really needed. As companies are responsible for the entire life cycle of their products, they have an economic incentive to design goods that are easily repairable, upgradeable and recyclable, as well as easy to maintain and disassemble. The

[28] https://ladiscussione.com/93595/ambiente/agroalimentare/generazione-z-punta-su-made-in-italy-e-sostenibilita/ [consulted on July 23rd, 2024]

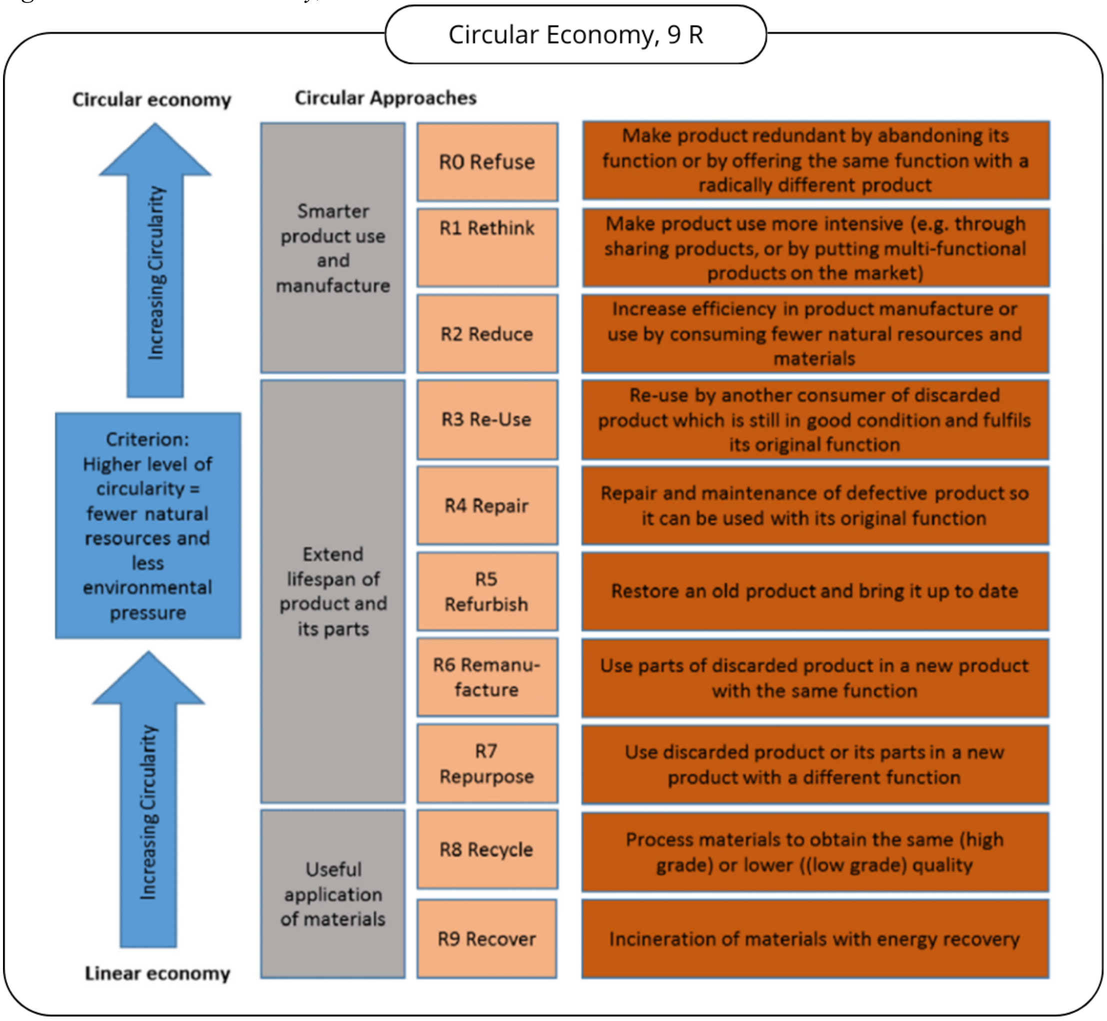
development of this service will not only reduce the extraction of raw materials, but will also reduce over-consumption, two problems facing modern society.[29]

3.1 Circular economy strategies

To move from a Linear to a Circular Economy, a change is needed to focus on strategies that narrow the use of resources, slow down the product cycle and close the material loop. There are five main ideas to follow: avoid using resources when not needed, make products life as long as possible, reuse and recycle materials, protect the environment and create value that is sustainable and shared by all. Companies need to take a leap forward and start thinking about their operations in a more sustainable way, rethinking on production processes and product management throughout the life cycle, making products last longer, reducing environmental impact while finding new ways to extend their life. This approach requires a global vision that includes the development of eco-design strategies so that every product is designed to be easily recyclable and free of hazardous substances. The Circular Economy places great emphasis on the protection of ecosystems, supporting all initiatives aimed to respect and protect biodiversity and natural sites. The change in mentality required to embrace the Circular Economy involves a profound change in the perception of waste, which is no longer seen as waste to be eliminated, but as a potential resource to be exploited. Turning what is considered waste into a valuable resource creates new economic opportunities and helps build a more resilient and Sustainable Economy. Based on these 5 theoretical foundations, the '9 R's' are a set of practical strategies for applying Circular Economy principles in business and everyday life, and can be applied individually or together. The first 3 R's are the design R's and require thorough evaluation and careful study to be successfully implemented. The next 5 are aimed at zero waste and are the 5 R's of consumption, while the last 2 R offer solutions for the sustainable elimination of waste, the R's of end of life in order to give to waste a way out. Below is reported a table explaining in detail the meaning and application of each strategy.

[29] https://circularity.com/circularguide/paas-product-as-a-service/ [consulted on June 14th, 2024]

Figura 10: Circular Economy, 9 R[30]



[30] Potting et al., (2017). *The 9R Framework of Circular Approaches with the production chain in order of priority.* p. 5

4.0 Circular economy measurement techniques

In order to fully understand the company’s as-is, it is essential to consider the three fundamental dimensions: environmental, social and governance, used to verify, measure, control and support the company's commitment. Specifically, ESG should primarily be linked to a set of criteria and standards for measuring assets and, in particular, the roadmap for analysing and expanding sustainable practices can be divided into four basic phases: Map and Measure, Monitor and Mitigate. These steps represent a systematic and integrated approach to mapping, analysing and improving the performance of companies in order to promote an effective transition to more Circular Business Models.

4.1 Map and Measurement

In the map and measurement phase, the as-is of the company is assessed through the lens of the triple bottom line, analysing environmental, social and governance dynamics.

The tool used in this analysis is the GRI standard, an universal guide to collect, analyse and report corporate performance. This tool helps companies to quantify and transparently communicate their business impacts, facilitating comparability between companies without misleading marketing strategies and ensuring transparent market competitiveness. The data collection follows two main sets, one universal and one specific, which analyses the governance, social and environmental dimensions, looking at both qualitative and quantitative data.

The universal standards are described below:

- GRI 1, Fundamental Principles: these guidelines are the starting point for the Report and define the principles underlying the document, such as accuracy, balance, clarity, comparability, completeness, sustainability context, timeliness and verifiability. Each principle is developed in detail and provides a guide to companies on how to gather information.
- GRI 2, General Disclosure: these guidelines outline the operational reporting environment, starting with the definition of organisational details, the definition of the reporting period, the highest governance body, and the

business management procedures listed in the 30 points reported in the standard section.

- GRI 3, Material Issues: the guidelines provide guidance on how to identify material issues, paying close attention to stakeholders and their concerns, how to identify and assess the company's impacts, and how to identify and manage the most relevant issues. The purpose of collecting qualitative data is to identify a company's identity and to understand its internal dynamics and external impact.

The specific standards focus on three main categories:

- GRI 200 examines corporate governance, reporting on 7 points from which to start a detailed analysis of the company's presence in the market. This allows a description of the company to be reported on key issues, such as the ratio of standard basic wages per gender to the local minimum wage, in order to facilitate the comparability of companies from a governance point of view.
- GRI 300 examines the natural resources used by the company and the resulting impacts. In particular, it provides guidelines for collecting detailed data on materials, energy, biodiversity, water, emissions and waste. For each category, information should be collected in a detailed and quantified manner.
- GRI 400 analyses the social theme, assessing in detail the management of workers' rights, analysing 19 dynamics ranging from employment, health and safety at work, training and parental leave, taking into account extreme dynamics such as child or forced labour.

A detailed survey is necessary to ensure the verifiability of the information and its reliability vis-à-vis stakeholders. This analysis, which directly and actively involves stakeholders, is considered essential to identify the most relevant material issues and thus guide strategic decisions, allowing the company's resources to be focused on aspects that create the greatest value for the organisation and its stakeholders.

4.2 Monitor

This step is essential to ensure that the promises made by the company to reduce its impacts are kept, and that the next Report reports results that are measurable and continually improving. The GRI standards provide guidance on how to write a

Sustainability Report. It is a non-financial statement that allows companies to maintain direct contact with their stakeholders and to highlight not only positive impacts but also negative ones. The Sustainability Report should not be written just to comply with mandatory regulations, nor should it be seen as a marketing tool to provide vague and unverifiable information. The purpose of the Report is to present information in a clear and transparent way.

One of the key tools is Materiality Analysis, which identifies the issues that matter most to the company and its stakeholders. Monitoring these issues means continually assessing their impact and relevance to ensure that the company's actions are aligned with stakeholder expectations and business priorities. The result of the Materiality Analysis is often presented in a Materiality Matrix, which graphically illustrates the relevance of each issue to the organisation and its stakeholders. Ongoing monitoring of the company's performance through the annual preparation of the Sustainability Report allows the company to proactively assess its impact and update strategies to meet new challenges. This activity not only ensures that the measures taken are effective, but also promotes a sustainable corporate culture. Employee training and the integration of sustainability into all business functions are essential to consolidate a sustainable approach.

4.3 Mitigate

Once impacts have been measured, the mitigation phase focuses on implementing concrete strategies to reduce the identified impacts. This phase requires a proactive approach to improving the efficiency of operations and reducing the company's overall environmental footprint by incorporating the following into the strategy:

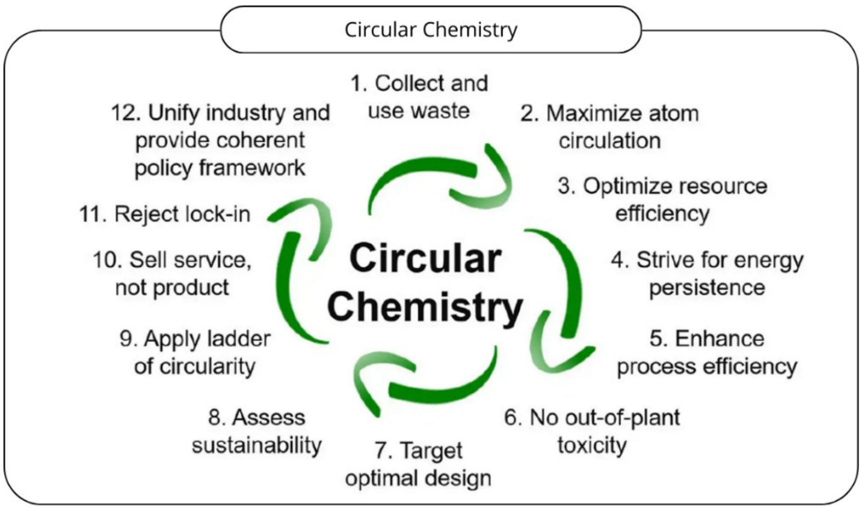
- Use of innovative materials with lower environmental impact
- Optimising production processes to reduce waste, improve energy efficiency and minimise emissions
- Implementing practices that maximise the efficient use of natural resources, reducing consumption of raw materials and non-renewable energy
- Develop packaging solutions that reduce environmental impact by using recyclable or biodegradable materials and minimising packaging

- Promote recycling and reuse practices that extend the life cycle of products and reduce the need for new resources
- Encouraging more sustainable consumption patterns such as shared consumption, product sharing and Circular Economy

Chemistry is the fundamental tool for using current knowledge and new research to lay the foundations for a new Circular Economy model that can replace the traditional linear system. In particular, Green Chemistry represents the new approach to chemistry, which is more responsible and sustainable, and aims to promote growth and development with a particular focus on human and environmental safety. These principles involve the redesign of chemical processes to reduce the use of harmful substances, the main obstacle to recycling. The need to reduce the negative impacts of the chemical industry to protect future generations has been the driving force behind the development of Green Chemistry. Every year, 220 billion tonnes of chemicals are released into the environment, causing over 9 million deaths. The World Health Organization (WHO) states that 22% of the global burden of disease and 24% of deaths are related to environmental factors, mainly pollution.

The twelve principles of Green Chemistry, which are fully in line with Europe's goal of zero climate impact by 2050, are reported in the following scheme:

Figura 11: Circular Chemistry[31]

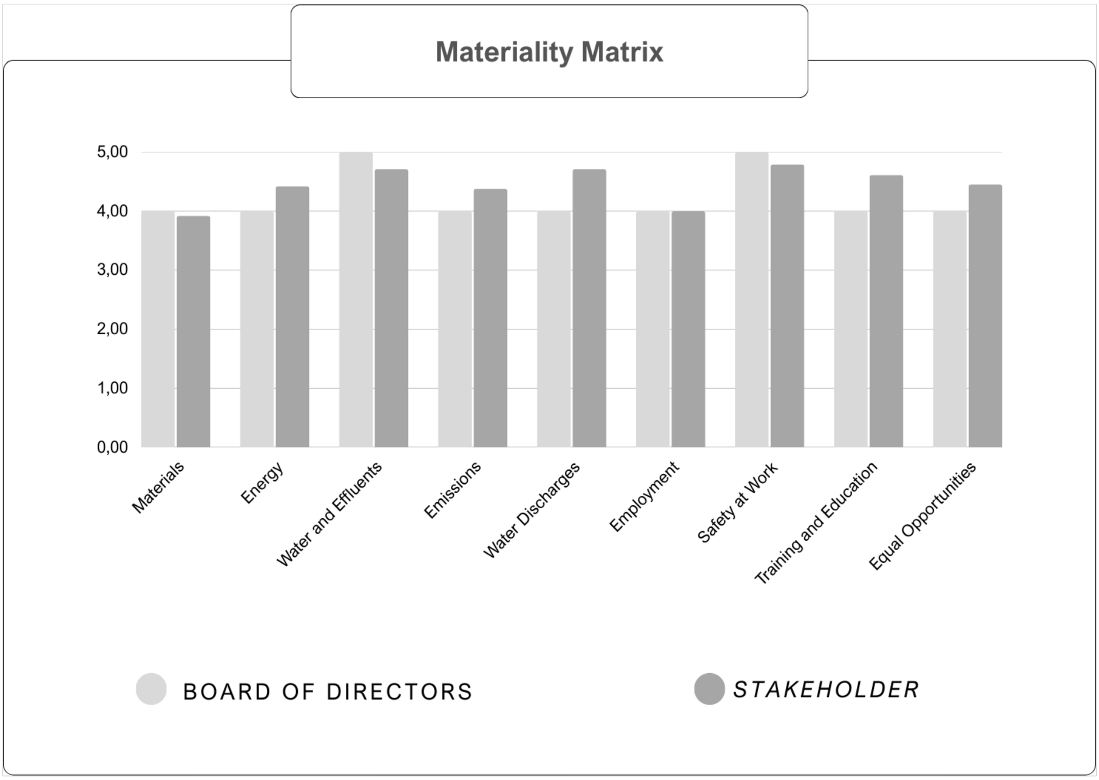


[31] https://hims.uva.nl/content/news/2019/02/the-twelve-principles-of-circular-chemistry.html?cb [consulted on July 16th, 2024]

5.0 Case study presentation and methodologies used for analysis

The most suppliers of large companies are small enterprises, creating a close link between large and small companies. In recent years, large companies focus on having a sustainable supply chain and to do this, their suppliers should undergo into this transition. The small company considered in the case study is an Italian company, located near Padua, whose name will be omitted for privacy reasons. The company analysed has been in the international market for over 20 years and meets the most advanced requirements in machining of mechanical parts of very high precision, below the hundredth of a millimeter. The materials used by the company are: AISI 316L, TITANIUM, brass, various alloy steels, 39NiCrMo3, 18NiCrMo5, 41CrAlMo7 and aluminum alloys 2011, 6082, 7075 ERGALL in addition to the normal so-called automatic steels, AVP, PR80, AVZ. The company's main products include components for cycles and motorcycles, components for the medical sector and furniture, components for the manufacture of clothing and high fashion accessories. The service that this company has requested is the writing of the Sustainability Report, in order to identify the as-is of the business reality and a road-tomap to identify possible implementations and suggestions for achieving a greater degree of sustainability, reducing CO_2 emissions. The drafting of the Sustainability Report was divided into 8 different meetings between the company reported and the one reporting, in which all the necessary data were collected. The Report was written following the contents of the International Framework of the Integrated Reporting Council and is in accordance with the guidelines GRI-Sustainability Reporting Standards, updated by the Global Reporting Initiative in 2021. Strategies to reduce CO_2 emissions have been developed from the examined points. During the first meeting between the reported and the reporting companies, a thorough Material Analysis was carried out to identify the points of the GRI Framework that are representative and those that are not. In particular, after identifying the material issues relevant to the company and excluding those that do not concern it, a survey was sent by e-mail to all customers, suppliers and employees of the company, to determine which issues were most important for stakeholders. Subsequently, a Materiality Matrix was developed, comparing the most relevant issues for both Stakeholders and the Board of Directors. The agreed themes were taken as a starting point for concentrating the company's efforts and improving these aspects to the maximum. The Materiality Matrix is reported below.

Figura 12: Materiality Matrix [32]



The first Sustainability Report for the company was drawn up and the plan of action was outlined in detail. In the following paragraphs, the points of GRI 301, 302 and 305 were analysed in detail and a road map was identified to make the company dynamics more sustainable. The GRI 303 and 306 points will be omitted in the analysis because the company has already activated a process change procedure to reduce the water consumption to waste. Changing the washing system of the pieces produced, consequently also the GRI 306 point remained marked, as in 2024 there was a clear reduction of both water withdrawals and discharges.

[32] Own development via Canva, based on the outcome of the case study investigation

6.0 Analysis of Raw Materials, GRI 301

In this analysis, the GRI 301 standard has been used as a guideline to examine the case study of the company under review. The guidelines provided by this standard relate the use and management of materials by organisations, with aim of outlining the current use of resources and providing a starting point for a more responsible sustainable management approach. The following 3 sub-sections examine: raw materials and products used in processing, materials used in the office and materials used in packaging, outlining the current situation and possible more sustainable implementation solutions.

6.1 Raw and Working Materials

The raw materials used by the company under review are metals for the manufacture of components for the bicycle, motorbike, and automobile industries, for the fashion, watch and luxury goods industries, for the furniture industry, and for the medical sector. Most of the precision machining of metals such as steel, brass, titanium, aluminium and iron is carried out in-house, while surface and heat treatments are outsourced to external suppliers. Below is reported a table explaining the quantity of raw materials used for the production of components in the years 2023, 2022, 2021. It should be noted that none of these inputs come from recycled materials.

Tabella 1, Input Data on Raw Material of the Case of Study. Own Elaboration

	2023	**2022**	**2021**
	Kg	**Kg**	**Kg**
Raw Materials - Metals			
Steel	13138	19177	21141
Stainless Steel	8356	8945	12712
Aluminium	5740	9632	12826
Brass	10713	22946	18091
Other Metals (Titanium, Bronze)	355	294	255
Raw Materials - Plastics			
Plastics	25	141	633
Raw Materials - Processing Products			

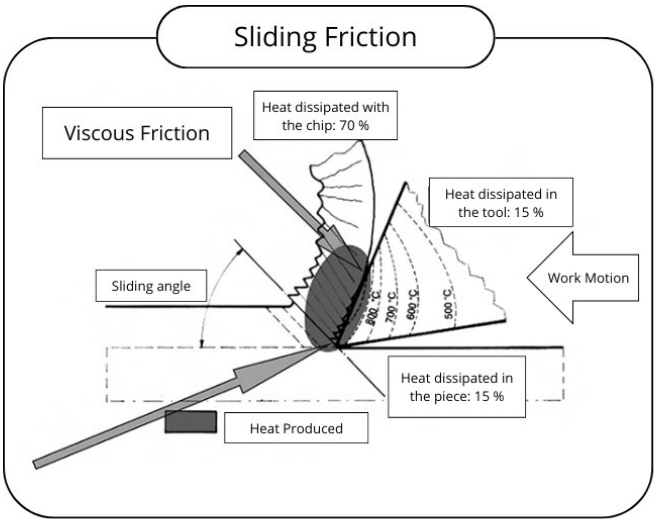
Chemicals (Mineral Oils, Detergents, Solvents)	4907	9130	8928

Particular attention should be paid to the 'Processing Products' category in the 'Chemicals' section of the table, where almost 5 tonnes of chemicals are used in 2023. It should be noted that the drastic reduction in the reported values is directly proportional to the amount of processed material, which decreases in 2023.

6.1.2 Chemicals for Processing, the role of cooling lubricants in the production process

In the metalworking industry, the use of cutting fluids is essential to lubricate tools, cool machined parts and facilitate the removal of chips produced during machining. In metalworking, the use of cutting fluids reduces the friction between tool and chips caused by the contact with the material being machined at high temperatures, limiting the tool wear. It is for this reason that the coolant is referred to as a 'liquid tool', capable of optimising machining processes, extending tool life and improving the surface finish of workpieces, thereby generating cost savings throughout the production process.

Figura 13: Sliding Friction[33]



In particular, two types of friction occur simultaneously during the machining process: on the one hand, a favourable viscous friction, which allows the chips to flow over the tool surface thanks to a thin layer of cooling lubricant; on the other hand, a particularly damaging

[33] Moscatelli D., Bellini M. and Apostoli P. (2011) *Evoluzione tecnologica nella lubrorefrigerazione e riduzione dei possibili effetti sulla salute degli esposti*

sliding friction, which is generated at the cutting edge of the tool, where the pressure exerted allows the material to be removed.
This latter friction is the main cause of tool wear, and this is why coolants are formulated with specific additives to limit its effect.

6.1.2.1 Chemical Composition

The characteristics of a cooling lubricant depend both on the base oil used and the additives that are added to it. The chemical composition of a generic cooling lubrificant is:

- Additives

In this context, additives play a fundamental role: while vegetable-based esters are naturally endowed with polar molecules and therefore do not need additives as they already have a strong lubricating power, specific additives are added to hydrocarbon-based oil in order to limit tool wear caused by sliding friction. The choice of additives influences oil performance in specific aspects such as detergency, cutting efficiency, anti-foaming capacity, mist reduction, antioxidant action and corrosion protection. The optimal choice of additives influences not only the properties of the oils but also the behaviour of the process, on the machine and in the environment. The most commonly used additive families can be divided into emulsifiers, corrosion inhibitors, stabilisers, extreme pressure additives (EP additives), anti-foaming additives and bactericides[34].

- Oil

The base oil helps to define basic properties such as viscosity, lubricity, flash point, tendency to evaporate, mist formation and smokiness.
In particular, there are two main families of base oils: those of vegetable origin and those of mineral origin. Below is shown a representative table of the main differences between the two oils:

34 https://www.biancogianfranco.com/Agg%20Area%20Italia/Lubrorefriger/Lubrorefrigeranti%20ad%20alto%20rendimento%20per%20il%20taglio%20e%20la%20rettifica%20degli%20ingranaggi.pdf [consulted on September 3rd, 2024]

Table 2. Oil's macrofamily[35]

Vegetable Base		Mineral Base
Rapeseed, Castor, Sunflower	**Origin of the Base**	Distillate of mineral oils
Renewable	**Risource**	Non-Renewable
Natural	**Chemical Composition**	Naphthenic - Paraffinic Hydrocarbons
High	**Adhesion (film)**	Low
Excellent	**Wetting Power**	Poor
Excellent	**Cutting Ability**	Good
Excellent	**Safety**	Acceptable
28 days 98%	**Biodegradability**	Years
Harmless	**Health Hazards**	Risky (IPA)
Positive	**CO_2 Impact**	Negative

- Water

Cutting and grinding fluids can be water miscible or non water miscible. Non-water miscible coolants are whole oils, while water miscible coolants are divided into 3 types: emulsifiable (mineral oil content > 40%), semi-synthetic (mineral oil content < 40%) and synthetic coolant (contains no mineral oil). The miscible metalworking fluid is diluted in water at concentrations that vary on average from 5% to 15% for machining and from 3% to 5% for grinding. Water is characterised by several parameters, including the chemical one, in which the variation in hardness with the presence of calcium, magnesium, iron, chlorides, sulphates and nitrite salts is particularly important, but also the biological parameter, in which the presence and/or variation of bacterial flora can influence the degree of deterioration of cutting fluids. In particular, hard water affects the chemical parameter directly, by affecting the stability of the emulsion, and the biological parameter indirectly, by facilitating bacterial growth and reducing the effectiveness of biocides. [36]

35 Lubrorefrigeranti%20ad%20alto%20rendimento%20per%20il%20taglio%20e%20la%20rettifica%20degli%20ingranaggi.pdf [consulted on August 23rd, 2024]

36 https://www.acquatecnicasrl.it/lubrorefrigeranti/ [consulted on August 23rd, 2024]

6.1.3 People – Planet – Profit analysis

The most widely used lubrication method worldwide is "flood cooling", where a large volume of cutting fluid is continuously sprayed onto the machining area to cool and lubricate the tool and workpiece, preventing tool wear and improving machining quality. This technique is also used in the company studied. Despite the effectiveness of flood cooling from an operational point of view, its use has environmental and health implications to be considered, as its consumption ranges is from 0.5 to 10 l/min. Globally, around 40 million tonnes of lubricants are used each year, many of which are not environmentally friendly and require complex and costly disposal methods. According to professor Paolo Bondioli, 30-35% of this huge amount is not recovered and is released into the environment. In Italy, on the other hand, 98% of cooling lubricant oil is collected, 90% of which is returned to the market after refining.[37] While the situation seems to be managed efficiently at the national level, it is not sufficient at the global level, resulting in environmental damage on a global scale. Below, is reported an analysis of the three dynamics: social, environmental and economic.

- Social Issues

In terms of social dynamics, one study showed that about 80 % of the illnesses found in workers using machine tools were related to exposure to cutting fluids, causing chronic conditions such as irritant contact dermatitis. Contact of harmful substances with the skin can cause allergies and skin diseases such as eczema, depending on the type of fluid and duration of exposure. Diseases of the digestive and respiratory systems can also result from ingestion of small particles and inhalation of refrigerant mist.[38]

The main health problem for workers is caused by PAHs present in mineral oils. These tend to increase during use due to the thermal stress generated during processing.
The following table shows PAH concentrations over three different time periods. [39]

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[37] https://www.innovhub-ssi.it/kdocs/2048685/webinar_-_biolubrificanti.pdf [consulted on September 13th, 2024]
[38] https://meccanicatecnica.altervista.org/gli-effetti-indesiderati-dei-fluidi-da-taglio-sulla-salute-delloperatore/ [consulted on July 23rd, 2024]
[39] https://www.bellini-lubrificanti.it/wp-content/uploads/2017/12/GIORNALE-ITALIANO-DI-MEDICINA.pdf [consulted on September 3rd, 2024]

Table 3: Concentration of PAHs in a new cooling oil and after 3, 6, 9 months of use. (Values expressed in ng/g)

Compound	New	3 months	6 months	9 months
Phenanthrene	2.5	11.2	64.5	370.0
Anthracene	0.6	3.1	19.5	141.0
Fluoranthene	5.1	6.9	32.0	49.9
Pyrene	21.8	35.9	101.8	120.1
Benzo-a-anthracene	2.9	7.0	32.9	26.8
Chrysene + Triphenylene	2.5	14.1	40.7	42.1
Benzo-e-pyrene	3.1	5.9	40.7	80.2
Benzo-a-pyrene	2.7	5.9	52.5	48.3
Perilene	3.6	6.2	42.0	56.7
Total	45.0	84.5	411.8	914.7

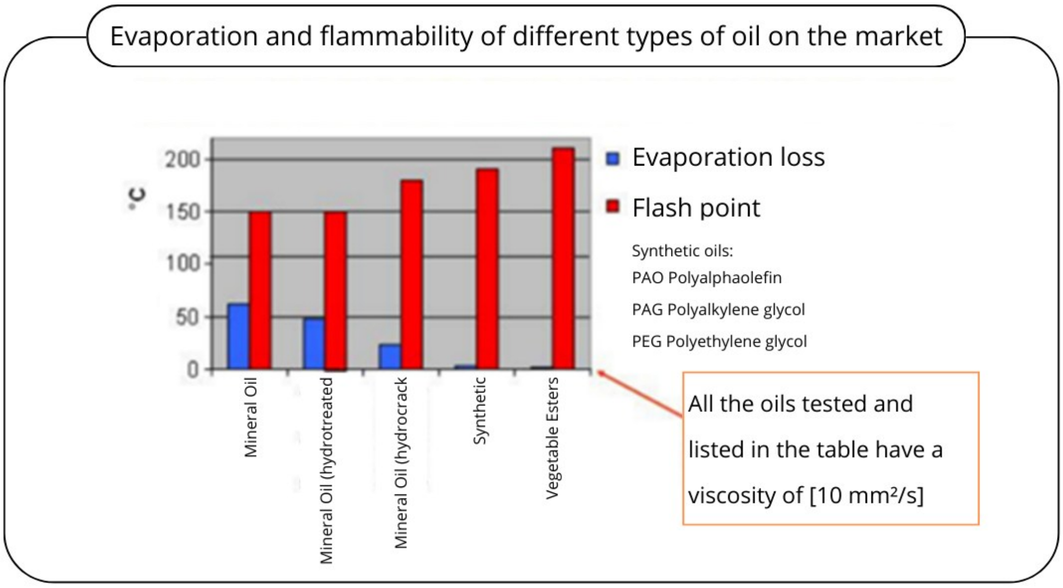
Another risk factor associated with water-soluble coolants is high bacterial and fungal growth. Synthetic fluids can promote the growth of bacteria, particularly gram-positive bacteria, increasing the risk of respiratory and dermatological infections among workers.[40] To reduce these risks, it is necessary to adopt preventive techniques that reduce the amount of fluid used and to install hoods or shields on machinery. Equally important is the cleaning of tanks and the use of biocides to reduce the microbial load. An additional risk is posed by oil mists that can form during high-temperature processing, exposing workers to skin and respiratory hazards. In fact, the International Agency for Research on Cancer has reported that non-vegetable oils can cause skin cancer.

Evaporation of oil at operating temperatures not only leads to increased consumption, but also pollutes the working environment, causing considerable damage to operators and increasing the risk of fire. From this point of view, the less an oil tends to

[40] Passman, F.J. and Rossmoore, H.W. (2002*). "Microbial Contamination Control in Cutting Fluids." Lubrication Engineering,* 58(6), 28-36.

evaporate, the better is. Vegetable esters are the most advantageous in many respects, as can be seen in the figure below.[41]

Figura 14: Evaporation and flammability of different types of oil on the market[42]



These risks can be reduced through the use of personal protective equipment (PPE). However, several Reports show that a significant percentage of companies, particularly small and medium-sized enterprises, tend to neglect the proper use of PPE, highlighting another major problem: a lack of awareness and training among workers and owners. Often, workers are not given enough information about the specific risks that PPE is designed to prevent, leading to a lower uptake of PPE.

- Economic Issues

41 https://www.biancogianfranco.com/Agg%20Area%20Italia/Lubrorefriger/Lubrorefrigeranti%20ad%20alto%20rendi mento%20per%20il%20taglio%20e%20la%20rettifica%20degli%20ingranaggi.pdf [consulted on September 3rd, 2024]

42 https://www.biancogianfranco.com/Agg%20Area%20Italia/Lubrorefriger/Lubrorefrigeranti%20ad%20alto%20rendi mento%20per%20il%20taglio%20e%20la%20rettifica%20degli%20ingranaggi.pdf [consulted on September 3rd, 2024]

Conventional fluids used in machining processes account for a considerable proportion of the total cost, ranging from 7% to 17%.[43]

The following table illustrates the costs associated with this technique worldwide, showing worldwide statistics by looking at one European country (Germany), one Asian country (Japan) and America (United States). This defines the economic influence on a company's choice of processing techniques, including disposal processes.

Economic Aspect of refrigerants (Source: web)

Country	Refrigerant Consumption	Disposal Cost	Total Cost
United States	100 million gallons	42 billion Japanese yen	71 billion Japanese yen
Japan	56 million tons	248 yen/ton	7% of total industrial waste costs
Germany	75 491 tons	N/A	16–30% of production costs

- Environmental Issues

From an environmental perspective, oil-derived fluids require proper handling and safe disposal to avoid contamination of soil and water resources. From this analysis, it can be concluded that the choice of lubricant-coolant should not be based solely on the purchase price, but also on cost-effectiveness in the highest sense of the word, taking into account the production cycle, its disposal and the health safety of employees. Green lubrication solutions are not only the most morally ethical choice, they can also offer companies a real opportunity to improve production processes while maintaining high quality. What is more, it improves the company's sustainable reputation, which is now an important factor that directly influence consumer choice.

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[43] Khanna N., Shah P., Sarikaya M. and Pusavec F. (2022) *Energy consumption and ecological analysis of sustainable and conventional cutting fluid strategies in machining 15–5 PHSS. Sustainable Materials and Technologies. Volume 32*

6.1.4 New Technologies and CE principles application

The theoretical innovation of sustainable science, based on the principles of Green Chemistry, prevents the use of substances that are harmful to the environment and society. In fact, sustainable processing techniques, which require the choice of non-harmful oils and the minimisation of the quantities used, are becoming established at industrial level. Strategies that prevent premature tool wear and facilitate the recycling of by-products (tools and chips) contribute most to the sustainability of machining. The aim of the proposed analysis is to analyse different types of innovative machining in order to develop proposals that reduce the negative impact on the environment and human health. New, highly efficient machining techniques that reduce social and environmental impacts are shown in the figure below.

Figura 15: Sustainable Machining[44]

This ring is a clear example of the application of Circular Economy techniques. In particular, this ring shows the following innovations: dry cutting without coolant, methods using minimal quantities of coolant and lubricant, cryogenic cooling or cooling with high-pressure supply of

[44] Krolczyk G. M., Maruda R. W., Krolczyk J. B., Wojciechowski S., Mia M., Nieslony P. and Budzik G. (2019). *Ecological trends in maching as a key factor in sustainable production, - A review. Journal of Cleaner Production. Volume 218, 601-615*

coolant/lubricant to the cutting zone, or the use of biodegradable oils as coolant/lubricant [45].

Industries that consider the adoption of sustainable operating techniques to be an essential element of their business are considering them after an expert assessment.

The following table shows a comparative analysis of the performance of different processing techniques on a scale of 1 to 5 (1 worst, 5 best):

Parametri	Dry Cutting	MQL/MQCL	Cryogenic	HPC	Biodegradable Oil
Initial Cost	5	3	2	1	4
Total Cost	3	5	4	3	3
Surface Finish	1	4	5	5	4
Tool Life	1	4	5	4	4
Energy Consumption	4	3	5	2	3
Sustainability	3	4	5	3	5
Cleanliness	5	4	5	2	2
Refrigerant Consumption	5	4	3	2	1

Table: a comparative analysis of the performance of different processing techniques

Dry machining and MQL are already well established on an industrial scale, have moderate costs in terms of both initial cost and energy requirements, and have low (or no) coolant consumption. The other options were not considered as they have lower parameters and require further study before being applied on an industrial scale.

6.1.4.1 Dry cutting

Dry cutting eliminates the use of the liquid tool just described, thus eliminating the use of harmful fluids for the operator and the cost of coolant. This particular process has already been widely adopted by several companies, with the economic success linked to the additional costs of disposal and removal of cutting fluid residues. This machining technique is considered to be the most sustainable form, provided that

[45] https://wwwsciencedirect.com/science/article/pii/S0959652619303968#tbl6

machinability indices are not compromised[46]. The machinability index of a material is expressed by definition as the percentage based on the relative ease of machining a material compared to free-cutting mild steel, which is 100% and taken as the standard[47]. With this technology, the 3 objectives of the CE have been considered and the environmental, social and economic dimensions have been achieved. The absence of coolant minimises the environmental impact, while at the same time avoiding the health toxicity of coolants and eliminating the cost of purchasing and disposing of cutting fluids. Although the environmental impact associated with the use of coolant has been eliminated, it must be remembered that each industrial reality produces specific pollutants in a complex mixture of fumes and dust, the composition of which can vary according to the type of material being machined. It is therefore essential to have proper industrial air filtration in order to prevent any health problems arising from exposure and to avoid secondary effects on machinery, technology and the quality of the final product, which would aggravate all three areas under consideration. One of the problems associated with the use of this innovation is the increase in temperature between the tool/work piece interface and the cutting edge, which can reach 1200°C[48]. This causes inefficiencies in both the workpiece and the tool. The main disadvantages associated with increased heat are the loss of tool hardness, dimensional accuracy and surface integrity. Therefore, the choice of material to be machined must be considered when using this process. The high temperature also affects the diffusion mechanism by which the atoms of the tool material are carried away with the chips. This process causes and accelerates the cratering of the tool, thus exacerbating tool wear due to abrasion[49]. Also due to heat, the area near the cutting edge can heat up and expand, creating a temperature difference with other areas of the workpiece, causing localised deformation and loss of accuracy. Chip removal is also a problem because at high temperatures it is soft and ductile and can stick to the workpiece and tool surfaces,

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[46] Krolczyk G. M., Maruda R. W., Krolczyk J. B., Wojciechowski S., Mia M., Nieslony P. and Budzik G. (2019). *Ecological trends in maching as a key factor in sustainable production, - A review. Journal of Cleaner Production. Volume 218, 601-615*

[47] https://www.sciencedirect.com/topics/engineering/machinability-index

[48] Wright P., McCormick S. and Miller T. (1980) *Effect of rake face design on cutting tool temperature distributions J. Eng. Indus., 102 (2) 123-128.*

[49] https://meccanicatecnica.altervista.org/degrado-e-usura-degli-utensili-da-taglio/ [consulted on July 23rd, 2024]

causing economic damage. In order to avoid premature tool failure and increase the quality of the machined part, the material and coating of the tools must be analysed, as they are extremely important variables that can definitely affect the thermal barrier.[50]

6.1.4.2 Minimum Quantity Lubrication

Another innovative method is Minimum Quantity Lubrication (MQL). This is an advanced lubrication technique that uses minimum quantities of cutting fluid, generally between 10 and 150 ml/h[51]. In this approach, a mixture of compressed air and a small amount of oil is sprayed onto the cutting area. Although air has a lower cooling capacity, the pure oil mixture helps to reduce friction and temperature, improving surface finish and extending tool life[52]. The cutting fluid used in MQL machining can be of either mineral or natural origin, but in this analysis we will focus on the use of biodegradable oils of natural origin. For machining to be considered sustainable, it must meet the following requirements: biodegradability of the cutting fluid, excellent chemical stability and high lubricating capacity, thus ensuring an environmentally friendly production process with low oil consumption. Vegetable oils have excellent biodegradability properties, but also other advantages, including better performance under pressure, increased metal removal rate and reduced losses through evaporation. With this method, the lubricant droplets supplied must be small enough to reach the cutting zone[53], but larger than 5-10 μm because the particles of a liquid remain in the air and could cause a health risk to the operator [54]. Their ability to penetrate the tool-chip interface and form a thin layer of fluid in a short time affects fluid efficiency and therefore tool wear. This technique can be applied both internally and externally, in the latter case without the need to modify the machine tool.

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[50] Krolczyk G. M., Maruda R. W., Krolczyk J. B., Wojciechowski S., Mia M., Nieslony P. and Budzik G. (2019). *Ecological trends in maching as a key factor in sustainable production, - A review. Journal of Cleaner Production. Volume 218, 601-615*

[51] Grzesik, W. (2008) *Dry and semi-dry machining, advanced machining processes of metallic materials*. 226–245.

[52] Nor Hamran N.N., Ghani J.A., Ramli R. and Che Haron C. H., (2020). *A review on recent development of minimum quantity lubrication for sustainable machining*. Journal of Cleaner Production 268 122165

[53] Park K. H., Olortegui-Yume J., Yoon M. C. and Kwon P. (2010). *A study on droplets and their distribution for minimum quantity lubrication (MQL)* Int. J. Mach. Tool Manuf., 50 (9) 824-833

[54] Thornburg J., Leith D. (2000). *Size distribution of mist generated during metal machining Appl. Occup. Environ. Hyg,* 15 (8), 618-628.

Specifically, with external minimal lubrication, the aerosol is delivered to the lubrication point from the outside through nozzles, eliminating the need to purchase a machine tool with internal minimal lubrication. One supplier of this technology reports that these systems increase tool life and improve production quality through more accurate surface machining. There are many operational, safety and environmental benefits to adopting this technology.

6.1.5 Overall Assessment of Methodologies

Numerous experiments were carried out on an industrial scale to explore the major differences between the traditional and the proposed innovative methods. The results were analysed by making an economic comparison.[55]

Analysis of the proposed methodologies

	Dry	Coolant	External MQL	Internal MQL
Tool life/Chip length (m)	12.4	44	55.2	96.8
Chip volume (cm^3)	397	1,408	1,766	3,098
Processing time (tool life in minutes)	1'46''	6'17''	7'53''	13'50''
Chip volumetric flow (cm^3/min)	14.2	14.2	14.2	14.2
Tool price (€)	60	60	60	60
Tool cost €/1,000 cm^3	153	42.16	33.97	19.37
Fluid cost €/1,000 cm^3	-	0.20	0.74	0.12
Energy cost €/1,000 cm^3	0.68	1.34	0.90	0.90
Compressed air €/1,000 cm^3	-	-	0.17	0.10
System investment €/1,000 cm^3	-	0.88	0.27	0.44
Fluid treatment €/1,000 cm^3	-	0.12	-	-
Filter cleaning €/1,000 cm^3	-	0.49	-	-

55 https://evolution.skf.com/it/la-lubrificazione-minimale-riduce-il-costo-totale-di-possesso/# [consulted on July 4th, 2024]

6.2 Office Materials

With regard to office consumption, such as stationery, the company uses only Ecolabel-certified paper. This certification guarantees that the paper comes from sustainable sources and is produced with a low environmental impact. Paper consumption is mainly related to production needs, such as order management and production sheets.

Paper Use	**2023**	**2022**	**2021**
	Kg	Kg	Kg
Ecolabel IT/011/004, FSC MIX	179	111	-

In recent years, companies have faced a number of operational and strategic challenges as a result of rapid technological development. It is now seen as an essential tool for all companies to improve their efficiency and maintain constant communication, promoting strategic partnerships between companies and thus industrial symbiosis.

Small and medium-sized enterprises in particular have experienced the greatest difficulties. According to data published by Istat in the report 'Imprese e ICT 2023', 47.9% of Italian SMEs use at least one management software, but only 13.6% share data with suppliers or customers within the supply chain (in the EU, the percentage is 23.5%)[56]. The result is a major blockage that prevents the construction of a solid network with concrete foundations. The foundation that a company needs to know and build its profit on is that a company never exists in isolation, but that overall performance depends on the entire supply network. Supply chain management is about managing the flow of information, products and services between the many 'chains' of operations and processes that make up an organisation's supply network. It is an essential activity because the overall success of an organisation depends crucially on the effectiveness of its supply network.[57] Technological innovation has made instant communication a management tool for businesses. In particular, dematerialisation, i.e.

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[56] https://www.istat.it/comunicato-stampa/imprese-e-ict-anno-2023/ [consulted on September 13th, 2024]

[57] Slack N., Brandon-Jones A. (2021) *Operations and Process Management, 6th Edition.*

the conversion of paper documents into electronic formats, is a key step in reaping the benefits of the digital transition. This transformation allows companies to significantly reduce their dependence on physical media, with immediate benefits in terms of accessibility and archiving. In addition to the external benefits of dematerialisation, there are also internal benefits. Searching for information within the organisation is much easier, and the operational costs associated with physical storage and document management can be significantly reduced. In addition, digitisation significantly improves data security, protecting information from potential loss or damage. In a world where quick access to information is crucial, document digitisation becomes a strategic element that promotes transparency between company, supplier and customer. The integration of digital technologies into business processes is no longer an option, but a necessity for Italian SMEs, which must face the challenges of digitisation with greater determination in order not to fall behind their international competitors.

6.3 Packaging Materials

In Italy, 10.470 million tonnes of packaging waste are recycled, representing 75.3% of the total amount released for consumption[58]. This high percentage has been possible thanks to continuous Research and Development, accompanied by the evolution of European legislation aimed at reducing packaging waste and making its life cycle more sustainable. In particular, Directive 94/62/EC[59], requires Member States to take measures to prevent the generation of packaging waste in order to achieve the recycling targets set for 2025 and 2030. In particular, it states that:

- At least 65% by weight of all packaging waste must be recycled by 31 December 2025
- At least 70% by weight of all packaging waste must be recycled by 31 December 2030.

[58] https://www.conai.org/notizie/riciclo-imballaggi-nel-2023-percentuale-in-crescita/#:~:text=Milano%2C%203%20luglio%202024%20%E2%80%93%20Nel,899mila%20tonnellate%20immesse%20al%20consumo [consulted on September 3rd, 2024]

[59] https://eur-lex.europa.eu/IT/legal-content/summary/packaging-and-packaging-waste.html [consulted on June 24th, 2024]

Among the essential requirements of this Directive, packaging must have a weight and volume based on the minimum quantity to ensure that the quality, hygiene and safety of the packaged product is maintained. The use of hazardous substances and materials must be minimised and its design must ensure that it can be recycled[60]. The reuse of packaging is essential to reduce the environmental impact of packaging production and disposal, thus reducing the consumption of resources and the amount of waste generated. It is therefore essential to introduce "Producer Responsibility" in companies, with the implementation of a return system for the reuse of packaging at the end of its useful life. Logistics therefore plays a central role throughout the supply chain. In detail, the packaging system can be divided into three levels, each with a specific role in protecting, handling and distributing the product:

- Primary packaging: a sales unit that comes into direct contact with the product and also performs a marketing function, ensuring the protection and attractiveness of the product to the end consumer.
- Secondary packaging: contains one or more primary packaging units and facilitates handling and transport within warehouses.
- Tertiary packaging: used to optimise the transport of multiple sales units, reduce handling and prevent damage during distribution[61].

In the packaging system, packaging information, such as labels, is essential for product traceability and safety throughout the supply chain and is required by Legislative Decree 116/2020, effective January 1, 2023. Research and Development have accompanied this Directive and numerous studies have been carried out on the use of lighter, yet more durable materials. Below is the definition of 4 criteria for sustainable

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[60] https://eur-lex.europa.eu/IT/legal-content/summary/packaging-and-packaging-waste.html
[61] https://www.conai.org/imprese/cosa-e-imballaggio/

packaging proposed by James et al. (2005) and adopted by the Sustainable Packaging Alliance:

Figura 16: Sustainable Packaging[62]

Environmental innovations must be carefully applied to avoid the risk of "under-packaging", caused by excessive reduction of packaging material that could damage products during transportation, with negative consequences related to increased waste.

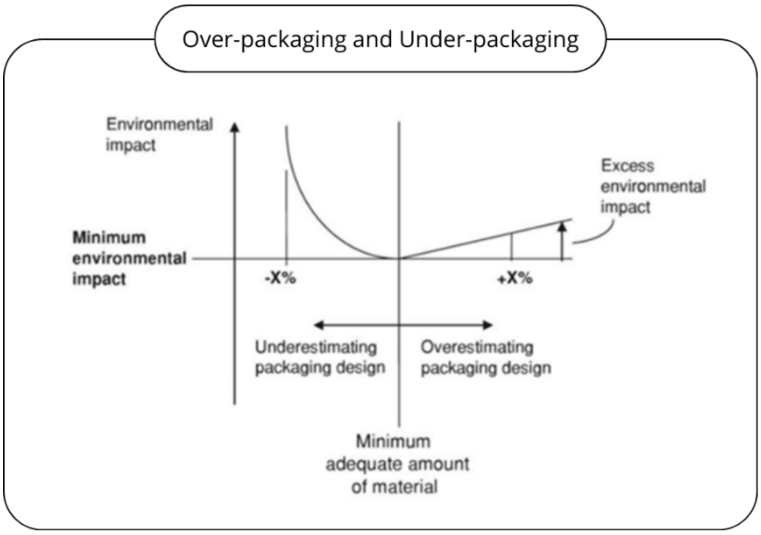


Figura 17: Over and Under packaging[63]

As pointed out by Verghese et al. (2012), packaging that appears sustainable may not actually be sustainable: excessive material reduction may cause more harm than good along the supply chain.

[62] SPA (Sustainable Packaging Alliance), www.sustainablepack.org [consulted on May 24th, 2024]
[63] Verghese K., Leanne Fitzpatrick H., (2012) *Packaging for Sustainability.*

When analyzing the packaging system, it is important to consider all actors in the supply chain, up to the consumer, to ensure that the packaging meets both environmental and ethical requirements, while respecting the safety of all parties involved.
For this case study, details of packaging consumption are shown in the table below.

Year	Paper/Cardboard	Plastic (net, bags)	Wood (% of reuse)	Stretch Film
2023	150 kg	13 kg	100%	39 kg
2022	310 kg	13 kg	100%	18 kg
2021	150 kg	13 kg	100%	65 kg

In particular, wooden pallets are reused until damaged, at which point they are disposed of as waste, while a return system for cardboard boxes has been implemented in collaboration with an FSC-certified incumbent supplier.
To comply with future legislation and reduce CO_2 emissions associated with packaging throughout the supply chain, several proposals to replace stretch film and non-recycled plastic bags have been considered.
More than 13,000 chemical compounds are used in the manufacture of plastics, of which more than 3,200 belong to the category of chemicals of potential concern.
The end-of-life of plastic packaging generally follows the boundaries of the Linear Economy, according to global data reported by the OECD:

- 79% of plastics are dispersed into the environment or end up in landfills
- 12% is incinerated
- 9% is recycled

The degradation of littered plastic in the ecosystem contaminates soil and water, releasing harmful chemicals. In addition, plastic waste has a long shelf life and good physical and chemical resistance, making it difficult for it to decompose spontaneously. Incineration of plastic waste produces particulate matter, which can cause lung disease. In detail, the following table shows the characteristics of burning conventional plastics and their health effects.

Tabella 3. Toxic compounds released from common plastics: ignition temperatures, combustion heats and health effects[64]

Toxic compounds released from common plastics

Name of plastic	Temperature of ignition K	Heat of combustion (MJ/kg)	Name of the compound	Effects on health
Polyethylene (PE)	623.15	46.3	Ethylene	Respiratory issues, potential carcinogenic effects
Polyethylene Terephthalate (PET)	773.15	22.7	Antimony	Respiratory issues, skin irritation, potential carcinogen
Polystyrene (PS)	743.15	41.6	Styrene	Irritation of skin, eyes, and respiratory tract, potential neurotoxin
Polypropylene (PP)	683.15	46.6	Additives (e.g., Phthalates)	Endocrine disruption, reproductive toxicity
Polyamide (PA)	773.15	31.6	Caprolactam	Skin, eye, and respiratory irritation, potential carcinogen
Polyvinyl chloride (PVC)	1033.15	19.26	Vinyl chloride, Phthalates	Carcinogenicity, liver damage, endocrine disruption

As a result, the production, consumption and disposal of plastics in today's world cannot follow the principles of a Linear Economy.

[64] Hussain M. A., Mishra S., Agrawal Y., Rathore D. and Chokshi N. P. (2024, 21 June). *A comparative review of biodegradable and conventional plastic packaging.*

The next table shows the materials, source and circularity of packaging, along with the resulting impact on human health and the environment.

Tabella 4. Comparison of biodegradable packaging materials[65]

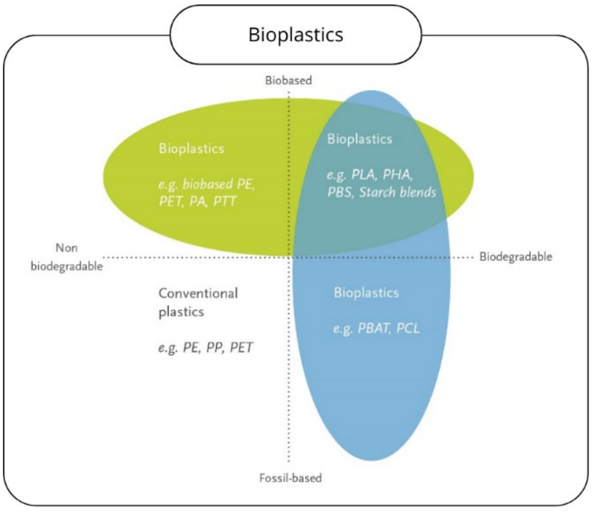
Comparison of biodegradable packaging materials

Material	Manufacturing	End of life	Circularity	Effects
Bio-plastics	Made from renewable resources like sugarcane, cassava, and corn	Biodegradable, breaks down in 6 months at home and 90 days in a commercial setting	Can be composted or recycled	Reduces greenhouse gas emissions, uses renewable resources
Inflatable air pillows	Made from biodegradable materials	Biodegradable, can be reused	Can be recycled	Reduces plastic usage, provides cushioning protection
Cornstarch packaging	Made from materials derived from the maize plant	Biodegradable, breaks down in 100 days	Can be composted	Competes with humans and animals who use corn as food
Mushroom packaging	Made using agricultural waste and mushroom roots	Biodegradable, breaks down in 100 days	Can be composted	Environmentally friendly, uses agricultural waste
Organic fabrics	Made from organic materials like hemp, palm leaves, recycled cotton, pineapple leaves, banana, tapioca, and many more	Biodegradable, breaks down in 100 days	Can be composted	Sustainable, biodegradable, and compostable
PLA packaging	Made from polylactic acid (PLA)	Biodegradable, breaks down in 12 months	Can be composted	Biodegradable, biocompatible, and non-toxic
PHA packaging	Made from Polyhydroxyalkanoates (PHA)	Biodegradable, breaks down in 12 months	Can be composted	Biodegradable, biocompatible, and non-toxic
Bagasse packaging	Made from sugarcane bagasse	Biodegradable, breaks down in 100 days	Can be composted	Sustainable, biodegradable, and compostable

[65] Hussain M. A., Mishra S., Agrawal Y., Rathore D. and Chokshi N. P. (2024, 21 June). *A comparative review of biodegradable and conventional plastic packaging.*

Among all biopolymers, Polylactic Acid (PLA) stands out as a highly suitable candidate due to its unique mechanical properties, which are comparable to those of conventional plastics used for packaging.

Figura 18. Bioplastics [66]



As shown in the reported diagram, PLA is classified as a biodegradable and biocompostable polymer. Its production takes advantage of microorganisms that can digest substances such as water, carbon dioxide and methane to produce biodegradable plastics.

It follows that the use of agricultural resources through fermentation processes to produce PLA has the potential to reduce carbon dioxide emissions, thereby helping to mitigate pollution and address the depletion of fossil fuel reserves.

It was analyzed that the production of 1 kg of PLA requires 1,6 kg of fermented sugar as feedstock due to its low resource use efficiency.[67] The study also examined the amount of land required to produce 1 ton of bio-based polymer using five different crops. The results showed that producing PLA from sugar cane or sugar beet requires only 0,12 hectares per ton, much less than the 0,32 hectares required to produce one ton of bio-based polyethylene (bioPE).

In general, the properties of PLA are similar to those of polystyrene in that it has a high modulus of elasticity (~3 GPa) and low elongation at break. However, PLA has a low heat distortion temperature (HDT), which prevents its use in applications above 55-60°C. This low HDT is the main limitation to using PLA as an environmentally friendly replacement for high temperature applications. Once PLA has exhausted all its functions, it can be disposed of in the wet fraction of waste collection.

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[66] https://www.european-bioplastics.org [consulted on September 11th, 2024]

[67] https://www.totalenergies-corbion.com/media/3vijlw5w/totalenergies corbion-biobased-pla-whitepaper.pdf [consulted on September 26th, 2024]

In this case study, stretch film is a plastic film used primarily to secure packages on pallets and to protect products during transportation, shipping, and storage. A polylactic acid stretch film is a viable option to replace classic stretch film made from non-recycled material. It is also recommended to replace the classic polyester tape used to seal paper and cardboard with a compostable PLA tape.

As for plastic bags, they are used as packaging to contain parts processed by the company and sent to the next supplier for assembly. Therefore, it is proposed to replace single-use bags with reusable bags, such as those made of recyclable fabric, by implementing a return system between the customer and the certified company. The packaging return system will be strengthened by the implementation of a route management system as proposed in section 7.2.3.

7.0 Presentation of energy vectors, GRI 302

The energy data was collected in accordance with the GRI 302 guidelines, which provide a comprehensive framework for the transparent assessment and monitoring of corporate energy consumption. By analyzing the collected data, the energy vectors used within the company were identified and then analyzed and evaluated in terms of consumption, efficiency and sustainability.

For the analysis of the energy vectors, it is useful to report the company's boundaries of interest: the organization’s boundaries of the case of study are extended over a total area of about 1,500 m2, where within the building there are offices (about 230 m2), the production area (about 760 m2), warehouses (about 360 m2) and the packaging and shipping area.

An analysis of the energy profile of the company's energy sources revealed the following: a PDR, two PODs, a photovoltaic system and diesel fuel. After a thorough analysis of the bills for 2023, the annual value of the energy sources is shown in the table. In order to compare the identified energy sources, the corresponding toe values are shown next to the data.

The conversion to toe was done according to the following parameters:

Type	Description	Unit of measurement	Conversion Factor	
Electric Energy	Electricity from the grid	kWh	kWh→toe	0,0001870
Fuel	Natural Gas	Sm^3	Sm^3→toe	0,0008360
Fuel	Diesel	liters	liters→toe	0,0008602
Electric Energy	Electricity from Renewable Sources	kWh	kWh→toe	0,0001870

2023	Internal Company Energy Requirements		
Vectors	**Value**	**toe**	**%**
Electric Energy from Grid, POD 1 (kWh)	268.513	50,2	54,0
Electric Energy from Grid, POD 2 (kWh)	98.124	18,3	19,7
Natural Gas (Sm^3)	6.735	5,6	6,0
Diesel (l)	3.418	2,9	3,2
Electric Energy from FER (kWh)	85.198	15,9	17,1
Total	93,1 tep		

The company's reality reflects a situation common to many Italian small and medium-sized enterprises, which are dependent on fossil fuels such as natural gas and diesel. This dependence on fossil fuels has a high environmental impact in terms of CO_2 emissions and a high economic vulnerability in terms of fluctuating energy prices. It is therefore crucial for Italian SMEs to consider energy diversification strategies and possible investments in renewable energy sources in order to improve sustainability and, above all, operational resilience.

In the company studied, Natural Gas is used exclusively for heating, while Diesel is used to power three trucks used for pick-ups and deliveries.

While both energy sources represent a relatively small portion of total consumption in terms of toe (6,0 % and 3,2 %, respectively), they contribute to a significant impact on CO_2 emissions, as illustrated in the next subsection. This reflects the key challenge facing many SMEs: balancing operational needs with the need to reduce dependence on fossil fuels.

In terms of electricity, the most important energy source for the company, a significant portion comes from a 100 kW photovoltaic system that operates since December 2022, with available datas from February 2023. This is an important first step towards energy independence and sustainability.

Based on the information reported in the company's energy diagnosis, detailed data on the company's energy consumption can be obtained, divided into three functional macro-areas. These areas make it possible to identify the most wasteful areas in terms of kWh and toe, providing a solid basis for analyzing the specific contribution of each function to overall consumption and for planning targeted energy efficiency improvement measures. The table below provides a clear overview of the company's energy consumption and highlights the critical areas where action can be taken to improve energy efficiency.

Macro-area	Functional Areas	kWh	toe
Main Activities	Machining centers and mills	182.778	34,2
	Turning	85.648	16,0
	Testing area	1.267	0,2
	Washing	5.270	1,0
	EDM (Electroerosion)	20.673	3,9
Auxiliary Services	Compressed Air	49.666	9,3
	Aspiration	5.808	1,1
	UPS	14.665	2,7
	Cart Charging	3.456	0,6
General Services	Lighting	37.145	6,9
	Offices	2.057	0,4
	Air Conditioning	40.588	13,2

As can be seen, the functional areas that consume the most toe are primarily related to manufacturing processes (such as machining centers and lathes) and general services (such as air conditioning and lighting). Below are the functional areas with the highest energy consumption in terms of toe, in descending order:

- Machining centers and milling machines (34,2 toe): are precision machining machine tools whose primary function is to transform raw materials into finished parts. Due to their intensive daily use and the power required to operate them, they are the highest energy consuming item.

- Turning (16,0 toe): is a machining process that removes material from a rotating workpiece to create symmetrical shapes. High energy consumption results from the continuous operation of lathes, especially in high-volume production.
- Air conditioning (13,2 tep): maintaining optimal conditions requires constant and often high consumption to ensure quality working conditions.
- Compressed air (9,3 toe): is a key energy resource in many manufacturing processes, but the compressors needed to produce it consume a significant amount of energy.
- Lighting (6,9 toe): includes fluorescent lighting found in company spaces such as offices, warehouses and production areas.

7.1 Analysis of CO_2 emissions, GRI 305

Based on the collected data, CO_2 emissions associated with each energy carrier were calculated using standard conversion factors, with the aim of evaluating their environmental impact.

The following table shows the values of the standard conversions performed in this analysis:

Type	Description	Unit of measurements	Conversion Factor	
Electric Energy	Electricity from the grid	kWh	kWh→ tCO_2eq	0,0002933
Fuel	Natural Gas	Sm^3	Sm^3→ tCO_2eq	0,0020040
Fuel	Diesel	liters	liters→ tCO_2eq	0,0026620
Electric Energy	Electricity from Renewable Sources	kWh	kWh→tCO_2eq	0,0000000

The results obtained will serve as the basis for identifying improvement opportunities and proposing potential actions to optimize energy consumption, increase the use of renewable energy and reduce dependence on fossil fuels.

		Bought		**Autoproduction**	
Energy Carrier	Category	Value	tCO_2eq	Value	tCO_2eq
Electric Energy from the grid, POD 1 (kWh)	Scope 2	268.513	78,8	-	-
Electric Energy from the grid, POD 2 (kWh)	Scope 2	98.124	28,8	-	-
Electricity from Renewable Sources (kWh)	Scope 2	-	-	116.615	-
Natural Gas (Sm³)	Scope 1	6.735	13,5	-	-
Diesel (l)	Scope 1	3.418	9,1	-	-

According with the Standard GRI 305-1, the Direct (Scope 1) GHG emissions can come from the following sources owned or controlled by an organization:

1. Energy Generation: emissions from fuel combustion in stationary equipment such as boilers, furnaces, turbines, and flaring processes.
2. Industrial Processing: emissions from manufacturing or chemical processing of materials like cement, steel, aluminum, ammonia, and waste treatment.
3. Transportation: emissions from mobile sources like trucks, trains, ships, airplanes, buses, and cars used for transporting materials, products, waste, and people.
4. Fugitive Emissions: uncontrolled emissions from leaks in equipment (e.g., joints, seals, and gaskets), methane leaks from coal mines or gas transport, venting, and HFC releases from refrigeration and air conditioning systems[68]

The following table summarises the tCO_2equivalent emissions from the use of fuels inside the company for transporting goods and from heating.

[68] https://www.globalreporting.org/publications/documents/english/gri-305-emissions-2016 [consulted on September 11th, 2024]

Vector	Category	Value	tCO_2eq
Natural Gas (Sm³)	Scope 1	6.735	13,5
Diesel (l)	Scope 1	3.418	9,1
Total	Scope 1	-	22,6

As a result, 60 % of emissions are caused by Natural Gas and the remaining 40 % by Diesel.

Scope 2, on the other hand, is particularly relevant because, for many organizations, the energy-related indirect greenhouse gas emissions (Scope 2) from purchased electricity can far exceed their direct emissions (Scope 1).

The GHG Protocol Scope 2 guidance requires organisations to provide two distinct Scope 2 values: location-based and a market-based.

- Location-based method: represents the average GHG emission intensity associated with electricity grids where energy consumption takes place, predominantly using average network emission factors.
- Market-based method: represents the emissions associated with electricity intentionally chosen by an organisation. This approach uses emission factors derived from contractual instruments, which may include power purchase agreements with generation attribute information or separate attribute declarations.

The following table summarises the tCO_2equivalent emissions from the use of Electric Energy from the grid. As can be seen, Electric Energy from FER is reported on datas, but its value is equal to 0 tCO_2eq. The first method considered is Location Based and the calculation to the national energy mix, equal to 0,0002933 tCO_2eq/kWh.

Vector	Category	Value	tCO_2eq
Electric Energy from the grid, POD 1 (kWh)	Scope 2	268.513	78,8
Electric Energy from the grid, POD 2 (kWh)	Scope 2	98.124	28,8

Electric Energy from FER (kWh)	Scope 2	85.197	-
Total	Scope 2	366.637	107,6

On the other hand, for what concern the Market-Based method, the conversion factor derived from the European energy mix chosen, as the distributor is a company operating in Europe, equal to 0,0004571 tCO_2eq/kWh[69].

Vector	Category	Value	tCO_2eq
Electric Energy from the grid, POD 1 (kWh)	Scope 2	268.513	122,74
Electric Energy from the grid, POD 2 (kWh)	Scope 2	98.124	44,85
Electric Energy from FER (kWh)	Scope 2	85.197	-
Total	Scope 2	366.637	167,6

The calculation assessing the company's energy sustainability is performed by determining the tCO_2eq emissions avoided through the use of self-generated and self-consumed photovoltaic energy within the company. For simplicity, this value is reported with a negative sign. It is derived by multiplying the self-generated and self-consumed kWh with the conversion factor for grid-supplied energy, which is equal to 0,0002933 tCO_2eq/kWh.

Vector	Category	Value	tCO_2eq
Electric Energy from FER (kWh)	Scope 2	85.197	- 25,0

[69] https://www.aib-net.org/facts/european-residual-mix/2022 [consulted August 26th, 2024]

7.2 Energy Carrier Innovations:

The following proposals aim to reduce energy carriers from fossil fuels. As one of the primary objectives, the use of Natural Gas and Diesel must be eliminated or made partially more efficient. Regarding the use of energy from non-renewable sources, all proposals focus on improving efficiency, till the final proposal, which advocates for the complete elimination of fossil fuel-based energy sources.

7.2.1 Renewable Energy

The company operates a 100 kW photovoltaic system that has been in service since December 2022, with available datas from February 2023. In its first year of operation, the system produced a total of 116.615 kWh. The self-generated energy was partly consumed internally to meet the company's energy needs (85.197 kWh) and partly fed into the grid (31.418 kWh). The energy fed into the grid represents surplus production during periods of low consumption but also constitutes an economic loss, as the minimal return from feeding energy into the grid is significantly lower than the cost of purchasing electricity from the grid during peak demand periods.

To enhance the efficiency of the photovoltaic system and maximize its environmental and economic benefits, it is proposed to install a storage battery. This device stores excess electricity produced by the photovoltaic system during daylight hours. The stored energy can then be utilized during periods when the system is not generating electricity or to meet peak consumption demands.

With the addition of a storage battery, the energy not immediately used for company operations would be stored instead of being fed into the grid.

This would allow the company to avoid drawing 31.418 kWh per year from the grid, resulting in significant economic savings and environmental benefits, including the avoidance of 9,2 tons of CO_2eq emissions annually.

$$31.418\ kWh/year \times\ 0{,}0002933\ tCO_2eq/kWh = 9{,}2\ tCO_2eq$$

The introduction of a storage system is therefore a fundamental tool for reducing the company's dependence on fossil fuels and cutting CO_2 emissions.

If the investment in a storage battery proves too costly from an economic perspective, a second sustainable option for managing energy surplus is recommended.

Specifically, a company aiming for sustainability must consider the potential impact of its activities both externally (on the local community) and internally (within the company itself). In this context, companies with photovoltaic systems can become the key drivers of Renewable Energy Communities (RECs), a new model for the production and sharing of renewable energy. This system fosters the creation of true communities that promote environmental sustainability by involving as many citizens as possible. In details, each member directly uses the energy produced by the system to meet their own real-time energy needs. Any energy not immediately consumed is fed into the local grid and shared with other REC members. If, despite the sharing, there is still unused energy within the REC, it is fed into the public grid. The company can chose to specific users, such as schools, hospitals, or public entities when sharing surplus energy, in order to bring the greatest possible benefit to the local community. Specifically, community members must be connected to the same "low-voltage node" of the power grid. Production systems must be powered by renewable sources and have a capacity not exceeding 1 MW. With its 100 kW photovoltaic system, the company complies with these requirements. By joining the REC, the company would demonstrate its proactive role in driving the energy transition.

7.2.3 Diesel

As previously mentioned, Diesel as fuel is used to power three trucks, which are used for goods pick-ups and deliveries. The efficient management of a company fleet is an essential point in order to contain the costs not only of Diesel fuel but also of vehicle wear and tear, as well as to reduce the environmental impact.

The first step towards greater efficiency of the company fleet is the monitoring of vehicle kilometres. This serves to optimise travel routes and make them as fuel efficient as possible. The monitoring of kilometres can be done manually by employees, but to ensure more accurate data quality, a transport management system could be implemented, so that route routes are examined from both an economic and environmental perspective. The transport management system is a useful tool, which

makes the distribution of products more efficient and provides greater visibility of all shipments.
The latter skill allows the company to maintain direct contact between the company and its customers/suppliers, securing strategic partnerships within a very competitive market, and additionally allows the company to keep abreast of market trends by receiving continuous feedback from customers/suppliers. In addition to the operational benefits just analysed, the transport management system will also provide greater security for the eventual implementation of the packaging return system, discussed in paragraph 6.3.
The next step towards energy efficiency is the adoption of electric vehicles. This choice requires a high initial investment and the financial savings are not sufficient to repay it, but sustainable mobility is considered a plus for the company's image and the lowering of CO_2 emissions.
The potential electric vehicle would be recharged using the company’s existing photovoltaic system, resulting in zero CO_2eq emissions and providing economic savings on fuel. A new sustainable purchasing method considers the product as a service (PaaS). This business model ensures that the initial cost of the product does not impact the buyer, who pays not for the product itself but for its corresponding rental service.
The actual economic savings for the buyer lie in the fact that the total rental cost often includes additional services such as maintenance and insurance, reducing the need to manage extra expenses. Any technical issues are thus handled by the service provider, with no additional costs for the customer, costs that would otherwise fall on the company in the case of vehicle ownership.
The option to rent state-of-the-art vehicles, which are more energy-efficient, can lead to reduced operational costs, such as fuel or energy consumption (in the case of electric vehicles). This also helps improve the company’s image, demonstrating a commitment to technological innovation and sustainability.
Moreover, at the end of the rental contract, the company can choose to replace the vehicle with a newer model or adapt the fleet to operational needs that may change over time.

The company's current situation presents a consumption of 3.418 litres of diesel per year, which corresponds to 9,1 tCO_2eq. If the company had a fleet of electric cars and not diesel, and if they were recharged at night thanks to the energy stored by the storage battery, the tonnes of CO_2 from renewable electric sources would correspond to 0 tCO_2eq.

In order to find out the equivalent of kWh based on litres consumed and to assess the actual rental of the electric car and whether it could be charged directly with the photovoltaic energy already present in the company, the following steps were followed:

Data:

- Annual diesel consumption: 3.418 liters
- Average kWh consumed by an electric car every 100 km: 19,07 kWh/100 km
- Average liters consumed by a combustion car every 100 km: 6,34 l/100 km [70]

Calculations:

To calculate the total distance traveled by the combustion car, the following formula is used:

Total distance (km) = Diesel consumption (liters) × 100 km / 6,34 l
Total distance (km) = 53.911,7 km

Next, the equivalent electrical energy required to cover the same distance with an electric vehicle is calculated. The formula is:

Equivalent electrical energy (kWh) = Total distance (km) × 19,07 kWh / 100 km
Equivalent electrical energy (kWh) = 53.911,7 km × 19,07 kWh / 100 km = 10.281 kWh

Result:

This means that an electric vehicle would need 10.281,96 kWh of electricity to cover 53.911,7 kilometres. This value represents the total energy requirement to cover the same distance that an internal combustion car would cover with 3.418 litres of Diesel. The real consumption of energy required to recharge the vehicle, considering an efficiency of 80% is equal to: 12.851,2 kWh. The photovoltaic system can fully meet

[70] https://www.verbrauchskatalog.ch/it/informazioni/consumo [consulted on January 20th, 2025]

100% of the energy required to recharge the electric vehicle, eliminating 9,1 tCO_2eq associated with Diesel use.

7.2.4 Natural Gas

As presented in section 7.0, Natural Gas is used by the company exclusively for heating. From an analysis of the bills, in 2023, 6.735 Sm3 were used over 7 months to heat 9.688 m3.

Several solutions were considered to decrease the company's dependence on fossil fuels, which are reported and analysed below.

The first proposed solution includes an analysis of heat recovery from the compressor for company heating. This solution considered the ENEA study "Opportunities for optimising consumption in the production, distribution and use of compressed air in the most sensitive industrial sectors"[71], which states that up to 94% of the heat produced by the compressor can be recovered. This heat, which would otherwise be lost, can be used for applications such as space heating.

The breakdown of recoverable heat is as follows:

- 72% recovered through the cooling fluid of the compression unit
- 13% through the cooling of compressed air
- 9% from the cooling air of the electric motor

During operation, compressors convert most of the consumed electrical energy into heat, which is dissipated. This heat represents an unused energy resource that can potentially be recovered with the adoption of appropriate thermal recovery systems. It can then be reused to heat company premises, reducing the need for fossil fuels.

In this case study, the following aspects will be analyzed:

1. The percentage of the company's volume that can be heated using thermal recovery from the compressor;
2. The residual heating requirement and the integration of an electric heat pump to complete the heating process and permanently eliminate the company's dependence on Natural Gas;

[71] Anglani N., Mura P. (2010) L'Energia e lo Sviluppo Economico Sostenibile. *Opportunità di ottimizzazione dei consumi nella produzione, distribuzione, utilizzo dell'aria compressa nei settori industriali più sensibili. Agenzia Nazionale per le Nuove Tecnologie, l'energia e lo sviluppo economico sostenibile.*

3. The sustainability of the system and its integration with a photovoltaic system.

Data:

- Compressor power: 30 kW
- Annual compressor consumption: 49.666 kWh
- Total volume of the building area to be heated: 9.688 m³
- Duration of the heating period: 7 months per year
- Heat recoverability: 94% of the energy consumed by the compressor
- Calorific value of natural gas: 10,69 kWh/Sm³[72]

Calculations:

To determine the total thermal energy requirement, the following formula is used:

Total thermal energy requirement = Gas consumption × Calorific value

Total thermal energy requirement = 6.735 Sm³ × 10,69 kWh/Sm³ = 71.997,15 kWh (thermal)

Next, the company's specific heating requirement for the heating period is calculated using the formula:

Specific heating requirement = Total thermal energy requirement / Total volume

Specific heating requirement = 71.997,15 kWh / 9.688 m³ = 7,43 kWh/m³

According to data from ENEA, 94% of the energy consumed by the compressor can be recovered as thermal energy. On an annual basis:

Annual recoverable heat = Annual consumption × 0,94

Annual recoverable heat = 49.666 kWh × 0,94 = 46.686,04 kWh/year (thermal)

Assuming the compressor's energy consumption is evenly distributed across 11 months, excluding August, the monthly consumption is:

[72] https://www.mcter.com/sostenibilita-ed-efficienza-energetica-in-azienda-27606#:~:text=Uno%20metro%20cubo%20di%20gas,kWh%20e%200%2C01%20mWh [consulted on September 18th, 2024]

$$\textit{Monthly consumption} = 49.666\ kWh\ /\ 11\ month = 4.515\ kWh/month$$

The heating period, as identified from the energy bills, lasts for 7 months, from October to April. The recoverable heat for this period is calculated as follows:

$$\textit{Compressor consumption (7 months)} = \textit{Monthly compressor consumption} \times 7\ \textit{months}$$

$$\textit{Compressor consumption (7 months)} = 4.515\ kWh/month \times 7\ months = 31.605\ kWh\ in\ 7\ months$$

$$\textit{Recoverable heat} = \textit{Compressor consumption (7 months)} \times 0{,}94$$

$$\textit{Recoverable heat} = 31.605\ kWh \times 0{,}94 = 29.709\ kWh\ (thermal)$$

To calculate the volume that can be heated using the recoverable heat, the following formula is used:

$$\textit{Heatable volume} = \textit{Recoverable heat (7 months)}\ /\ \textit{Specific heating requirement}$$

$$\textit{Heatable volume} = 29.709\ kWh\ /\ 7{,}43\ kWh/m^3 = 3.998{,}5\ m^3$$

Finally, the percentage of the company’s volume that can be heated using thermal recovery is calculated as follows:

$$\textit{Percentage of heatable volume} = \textit{Heatable volume}\ /\ \textit{Total volume} \times 100$$

$$\textit{Percentage of heatable volume} = 3.998{,}5\ m^3\ /\ 9.688\ m^3 \times 100 = 41{,}2\%$$

Conclusion:

From the analysis conducted, 41,2% of the company's volume can be covered by the thermal recovery from the compressor.

The remaining 58,8% of the company's volume, which is not covered, corresponds to:

$$9.688\ m^3 - 3.998{,}5\ m^3 = 5.689{,}5\ m^3$$

Given that the company of 9.688 m³ consumes 6.735 Sm³ of gas over 7 months, the gas consumption per unit of volume is calculated as:

$$\textit{Gas consumption per unit of volume} = 6.735\ Sm^3 / 9.688\ m^3 = 0{,}695\ Sm^3 \text{ per } m^3 \text{ over 7 months}$$

Consequently, the gas consumption for the uncovered volume corresponds to:

$$5.689{,}44\ m^3 \times 0{,}695\ Sm^3 \text{ per } m^3 \text{ over 7 months} = 3.954{,}16\ Sm^3$$

Based on this initial option, considering that 1 Sm³ = 0,0020040 tCO_2eq, the estimated savings amount to:

$$6.735\ Sm^3 - 3.954{,}16\ Sm^3 = 2.780{,}84\ Sm^3$$

$$2.780{,}84\ Sm^3 \times 0{,}0020040\ tCO_2eq/Sm^3 = 5{,}6\ tCO_2eq$$

Second Option:

Approximately 3.954,16 Sm³ of Natural Gas are used to heat the uncovered volume of the building over 7 months, equivalent to 42.269,98 kWh of thermal energy (calculated by multiplying by 10,69 calorific power). To completely eliminate dependence on fossil fuels, an additional solution is proposed: the use of an electric heat pump to complete winter heating and provide cooling during the 4 summer months.

Heat pumps are playing a central role in the energy transition. According to the IEA Report, “heat pumps currently available on the market are three to five times more energy-efficient than natural gas boilers.” Their operating mechanism leverages thermal energy, which means most of the heat is transferred rather than generated, resulting in high efficiency.

The efficiency of a heat pump is measured by the Coefficient of Performance (COP), which is the ratio of energy output (heat delivered to the space being heated) to electrical energy consumed. The higher the COP, the more efficient the machine. According to the "Solar Power Heats 2023" Report by SolarPower Europe, the savings achieved with a photovoltaic system combined with a heat pump range from 62% to 84%, depending on the country, energy price fluctuations, and weather conditions.
For both heating and cooling needs, a heat pump is used. The assumed efficiency is 4 (COP = 4).[73]
Based on this data, the analysis of the problem proceeds as follows:

Electricity required for heating = Thermal energy (heating) / COP
Electricity required for heating = 42.269,98 kWh thermal / 4 = 10.567,5 kWh

From the energy diagnosis, the air conditioning system is found to consume 40.588 kWh per year.
Combining the energy needs for cooling and heating with the photovoltaic system's energy production reported below (kWh), the following calculation is made:

January	February	March	April	May	June	July	August	Septemper	October	November	December
3.273	6.089	9.517	13.107	11.906	16.278	17.127	15.017	12.269	7.124	4.909	3.273

Since the production data of the photovoltaic system for January were not reported by the company, the same production as in December 2023 is estimated.

Total production over 7 heating months (October, November, December, January, February, March, April):

[73] https://biblus.acca.it/cop-pompa-di-calore-cos-e/?utm_source [consulted on June 4th, 2024]

Total production (7 months) = 7.124 + 4.909 + 3.273 + 3.273 + 6.089 + 9.517 + 13.107 = 47.292 kWh

The photovoltaic system fully covers 100% of the total heating demand.

Cooling Demand:
To calculate the total production of the photovoltaic system during the cooling months:

Total production over 4 cooling months (May, June, July, September) = 11.906 + 16.278 + 17.127 + 12.269 = 57.580 kWh

The photovoltaic system fully covers 100% of the total cooling demand.

Conclusion:
Analysis of this data shows that the photovoltaic system is sufficient to generate enough electricity to meet the energy needs of both the heat pump and to recharge the electric car, even without the implementation of a storage battery in the photovoltaic system.
In 2024, there are several tax incentives that favour the purchase of more advanced energy solutions. One example is the Ecobonus, which provides tax deductions of up to 50%.

7.2.5 Energy Analysis

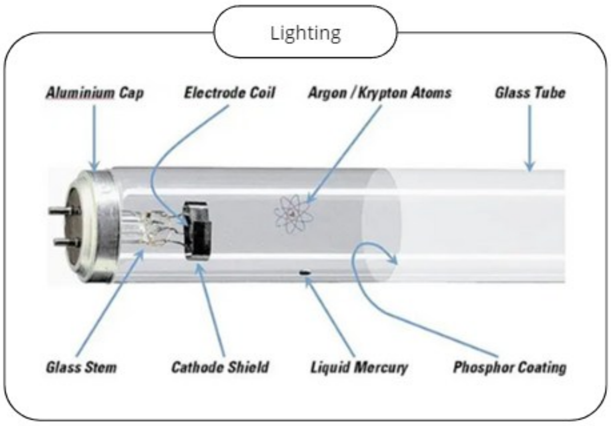
The purpose of the following analysis of electricity use is to identify innovative solutions to make its utilization more efficient.

7.2.5.1 Lighting

Regarding lighting, the high energy consumption is directly attributable to the use of fluorescent lamps. These are subject to numerous regulations at both European and national levels, not only due to their energy efficiency but also because of the hazardous substances they contain.

The current lighting scenario within the company is analyzed below, along with a more efficient and innovative alternative is proposed.

Figura 19: Fluorescent Lamp[74]



As shown in the image, fluorescent lamps consist of a sealed glass tube containing a small amount of mercury and the noble gas argon, under a pressure of 2-3 mmHg. At the ends of the tube are two electrodes that release electrons when an electric current flows through them.

The released electrons collide with argon atoms, causing their excitation and ionization. The ionization of the noble gas also facilitates the ionization of mercury, which quickly changes its state from liquid to gas. This process occurs because the energy required to ionize the noble gas is only slightly higher than that needed to ionize mercury, with a minimal difference ranging from 11,5 V to 10,4 V. However, to initiate this process, an electrical voltage of 400 V is required, whereas the standard voltage supplied by the power grid is 230 V. To achieve the necessary voltage for starting the process, a starter and a ballast are used.

Specifically, the excited mercury electrons emit ultraviolet light with a wavelength of 53,7 nm. The purpose is to convert this UV light into visible light. For this reason, the inside of the tube is coated with fluorescent powders that transform UV rays into visible photons.

Fluorescent lamps are generally more cost-effective and, due to the lower initial investment required, are often the first choice despite their lower efficiency.

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[74] https://www.luxemozione.com/2008/01/neon-no-lampade-fluorescenti-principio.html [consulted on September 13th, 2024]

In the current scenario, fluorescent lights in the company consume 37.145 kWh annually, equivalent to 6.9 toe and corresponding to 10,89 tCO_2eq emissions.
At the legislative level, several efforts are being made to promote the climate transition. Current European regulations, particularly Regulation 2019/2020 on Ecodesign for Lighting Systems, mandate that starting September 1, 2023, only energy-efficient light sources such as LEDs may be marketed in the European Union. This regulation is part of the European Climate and Energy Strategy, aimed at reducing energy consumption and environmental impact.
The rules are based on the implementation of the Single Lighting Regulation and the Energy Labeling Regulation, which ban inefficient light sources. Moreover, the RoHS Directive limits the use of hazardous substances such as mercury found in fluorescent lamps. Consequently, traditional fluorescent lamps can no longer be placed on the market from specific dates in 2023, driving the transition toward more ecological and sustainable LED lighting solutions.
The proposed scenario involves a drastic shift to LED technology. LEDs are highly efficient, consuming up to 50% less energy than fluorescent lamps for the same light output and boasting a lifespan of over 100.000 hours compared to 10.000 hours for a fluorescent lamp[75].
Regarding luminous efficiency, LEDs typically achieve 90 to over 100 lumens per watt, compared to 60 lumens per watt for compact fluorescent lamp. LEDs are light-emitting diodes that generate light through photon emission. When electric current flows through the semiconductor inside the LED, electrons combine with "holes" in the material's atomic structure, releasing energy as photons, which produce visible light. This process makes LEDs more efficient and durable than fluorescent lamps.
In details, when replacing a fluorescent lamp with LED technology, the power consumption per unit decreases from 0,116 kWh to 0,05 kWh.
For a fluorescent lamp operating for 10 hours per day over 287 days (11 months excluding Sundays and the month of August):

$$\textit{Daily consumption} = 0{,}116\ kWh \times 10\ hours = 1{,}16\ kWh/day$$

$$\textit{Total consumption} = 1{,}16\ kWh/day \times 287\ days = 332{,}92\ kWh/year$$

[75] https://www.iluminarinc.com/led-lights-v-fluorescent-bulbs/ [consulted on September 11th, 2024]

The corresponding emissions per fluorescent lamp corresponds to:

$$0{,}0002933\ tCO_2eq/kWh \times \mathit{332{,}92\ kWh/year} = 0{,}097\ tCO_2eq$$

For LEDs, with a power consumption of 0,05 kW, the total annual consumption is:

$$\textit{Daily consumption} = 0{,}05\ kWh \times 10\ hours = 0{,}5\ kWh/day$$
$$\textit{Total consumption} = 0{,}5\ kWh/day \times 287\ days = 143{,}5\ kWh/year$$

The corresponding emissions per single LED corresponds to:

$$0{,}0002933\ tCO_2eq/kWh \times 143\ kWh = 0{,}042\ tCO_2eq$$

The CO_2eq emission reduction per lamp replaced is equal to:

$$0{,}097\ tCO_2eq - 0{,}042\ tCO_2eq = 0{,}055\ tCO_2eq$$

This value is equivalent to 55 kg of CO_2eq avoided annually per single replacement. The economic sustainable evaluation considers the Product as a Service (PaaS) model, which is reshaping purchasing in the modern economic landscape. Instead of selling individual products, PaaS emphasizes renting the product, with all associated costs, including repairs and maintenance, borne by the owner-manufacturer. This approach ensures extended product lifecycle management, reducing waste and avoiding planned obsolescence. Partnerships are essential, focusing on managing the supply chain more efficiently and ensuring proper recycling or disposal. When lamps need replacement, the costs fall on the manufacturer, ensuring high-quality disposal or maintenance. Additionally, this simplified management system facilitates recycling by centralizing the products, eliminating inefficiencies in long supply chains. The transition to LEDs within this framework not only promotes environmental sustainability but also aligns with modern business strategies for waste reduction and Circular Economy practices.

7.2.5.2 BACS System

To improve the overall energy management efficiency of the company, the implementation of a Building Automation and Control System (BACS) is proposed. This system enhances energy efficiency by automating and optimizing daily operations, providing greater control.

BACS reduces energy consumption, thereby contributing to lower CO_2 emissions. It enables more efficient control and management of systems, including climate control, lighting, and electrical load management. The system offers real-time monitoring, with automation capable of following either predefined schedules or dynamic adjustments, supported by the integration of sensors.

7.2.5.3 Grid-source Energy

To further reduce CO_2 emissions, it is recommended to source grid electricity exclusively from renewable energy. This would add value to the company's sustainable products by limiting pollution and the use of fossil fuels.

By doing so, the company would qualify for a Guarantee of Origin (GO), a certificate issued by the GSE that certifies the renewable origin of the MWh purchased.

With the successful implementation of the proposed measures, the company would completely eliminate natural gas consumption, and renewable energy would become the sole energy carrier within the organization. Consequently, CO_2 emissions link to energy vectors would be reduced to zero tCO_2eq.

8.0 Certifications and Conclusion

From a strictly geopolitical point of view, the planet is divided into States, but from a biological point of view, it represents one large, interconnected ecosystem. Because of the large and deep disparities in development between different areas of the world, sustainability management must necessarily be organised on a state-by-state basis.

Each State may or may not have the resources to promote sustainability, influencing sustainable management positively or negatively both on the microscale, from the individual citizen, and on the macroscale, from companies to the entire supply chain.

The ultimate goal of the 2030 Agenda is to reduce the number of States lacking the means to adequately manage sustainability by encouraging parity between them.

However, the real challenge is not only of a technical-structural nature, i.e. bringing resources and skills to the least developed countries, but also the education of the individual citizen.
Many people, despite having the means to act sustainably, choose not to do so, judging such action to be less costly in the immediate term, ignoring the long-term consequences for the world's population.
All States are based on an economic structure, which, as pointed out in Chapter 1, is most influenced by small and medium-sized enterprises, which are also the major source of pollution.
This is where more attention must be paid, not only by directing and guiding SMEs towards sustainable practices, but also by investing in their environmental and social education. This approach is set to become increasingly crucial in the transition to global sustainable management.
A very important means that is guiding both consumers and companies towards choosing sustainable suppliers and/or companies are Sustainability Reports.
When a company decides, or is obliged, to draw up a Sustainability Report, it should not be conceived as a marketing tool. It is essential that the Sustainability Report not only shows the aspects that companies manage sustainably, but as the Gri Standards emphasise, also and above all the critical areas that are not being managed optimally. It is this transparency that distinguishes Sustainability Reports from a marketing strategy, as long as it is written in a regular manner and relevant to the Standards under review.
At the same time, consumers must be adequately protected against false or misleading or unverified advertising claims. Many consumers, attracted by products labelled as ‘green’, preferred to spend more, trusting statements made by companies that were often unfounded.
Certifications are fundamental tools for ensuring correct data processing and optimal management in the selection of suppliers on a large scale. The more a company is able to demonstrate its commitment to environmental and social sustainability through the acquisition of recognised certifications in Sustainability Reports, the greater the economic benefit it will be able to derive, creating a virtuous circle between sustainability and profit.

In the company analysed, various certifications can be taken into consideration to demonstrate its active and transparent commitment to environmental, social and economic sustainability, which are essential for correct and transparent data processing and large-scale supplier management/selection.

From the point of view of environmental sustainability, ISO 5001 is considered. This standard sets out the requirements for developing, implementing, maintaining and improving an energy management system. The objective is to enable the organisation to continuously improve its energy performance through a structured approach. The energy resources included include electricity, fuel, steam, heat and compressed air.

ISO 50001 specifies the criteria necessary to create, initiate and optimise an energy management system, while offering guidelines for its implementation. This standard covers the procurement, storage and use of energy resources, including measurement, documentation, reporting, design and procurement of equipment, processes and personnel involved in energy management. The system is designed to promote continuous improvement, increasing energy efficiency and optimising energy consumption and use.

The measurement of CO_2 emissions is a crucial aspect in obtaining various certifications. Among these, ISO 14064 certification plays a key role in ensuring the reliability and credibility of greenhouse gas (GHG) monitoring and reporting processes. This standard applies to both corporate reporting on emissions and projects aimed at reducing them.

Another standard to take in account is PAS 2060, issued in 2010 by the British Standard Institution (BSI), it is internationally recognised and applicable to organisations of all sectors and sizes.

This standard helps companies to improve their carbon neutrality performance and provides greater transparency in climate neutrality claims, ensuring a uniform approach to calculating greenhouse gas emissions, their reduction and offsetting, and final reporting. PAS 2060 traces a clear path towards decarbonisation: it starts with the calculation of CO_2 emissions, continues with their reduction through the carbon footprint (following the ISO 14064) and arrives at the offsetting of unavoidable emissions. The offsetting of CO_2 takes place through the use of certified carbon credits, verified by a third party, which ensures the absence of carbon leakage phenomena (shifting of emissions to other areas) and avoids double counting (double counting of the same reductions or removals). PAS 2060 certification is only granted after a validation process of the actions taken, which are properly documented. The main benefit of this standard is the active involvement of stakeholders through verification and transparency of statements, reducing the risk of greenwashing practices. PAS 2060 certified companies achieve:

- Optimising resources, reducing energy consumption and cutting operating costs;
- Access to new markets and targeted investment funds;
- Improved competitive positioning, customer loyalty and new customer acquisition.

Furthermore, the Carbon Trust Standard, a performance certification, is a globally relevant certification that rewards best practice and achievement in reducing carbon emissions. Companies that obtain this certification must demonstrate an accurate assessment of their carbon footprint, based on solid, verifiable data.

In addition to regulatory standards, there are several voluntary programmes that quantify the sustainability performance of organisations, both environmentally and socially.

B Corp certification is a third-party certification that requires organisations to meet high standards of social and environmental performance, as well as accountability and transparency to stakeholders. Issued by the global non-profit network B Lab, B Corp certification aims to transform economic systems by promoting a more inclusive, equitable and regenerative economy.

In addition to environmental standards, there are specific certifications that assess the social performance of companies, ensuring fair and respectful working conditions for employees.

SA8000 is the world's leading social certification standard, developed by Social Accountability International (SAI).

It provides a management framework that helps companies operate in a fair and respectful manner towards workers, demonstrating compliance with the highest social standards.

SA8000 is a management system standard applied to the social aspects of work. It assesses companies' performance in eight key areas of social responsibility in the workplace:

- Child Labour: prevention and prohibition of the use of child labour;
- Forced Labour: prohibition of all forms of forced or coercive labour;
- Health and Safety: ensuring a safe and healthy working environment;
- Free Association and Collective Bargaining: right of workers to organise and bargain collectively;
- Discrimination: prohibition of discrimination based on gender, ethnicity, religion, sexual orientation and other factors;
- Disciplinary Practices: prohibition of abusive or insulting disciplinary practices;
- Working Hours: compliance with international standards on working hours;
- Remuneration: ensure that wages are fair and in line with local and international standards.

Adopting the SA8000 standard enables companies to improve human resources management, promote a corporate culture based on respect for human rights and gain a competitive advantage in the marketplace.

This certification is particularly appreciated by companies that want to demonstrate their ethical commitment to workers and meet the growing expectations of customers and stakeholders in terms of corporate social responsibility.

With the rise of the Circular Economy, the profit perspective is only one of three dimensions to be considered: environmental and social sustainability have become increasingly closely monitored and regulated factors.

To ensure the development of sustainable management systems on a large scale, it is necessary for every citizen, whether as an individual, entrepreneur or educator, to comply with the sustainability criteria set by the European Union. More and more companies are adopting ‘return-to-supplier’ policies, which allow consumers to return products to be dismantled, repaired or recycled directly by manufacturers, thus reducing waste and optimising material recovery. Sustainability is thus seen as a responsibility that extends from the state, runs through companies and involves every single citizen.

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