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Management for Energy and

Environmental Transition

Carbon Accounting e KPI: un'analisi della conformità agli standard nel contesto europeo

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Abstract

This academic thesis aims to analyze the management and reporting of KPIs concerning GHG emissions in the business landscape. It faces European regulations, as with the introduction of the new European CSRD directive and its ESRS standards, companies must now report on this information following specific guidelines and regulatory obligations. The focus, therefore, will be on the variability of these guidelines and standards and on the suggested metrics and how these can influence business strategies and objectives. The empirical analysis will try to understand how a growing adoption of sustainable practices, despite differences in approaches and data quality, influences impact monitoring, highlighting how carbon accounting is not just a mere regulatory requirement but an excellent tool to increase operational and financial efficiency. Finally, it will try to understand, through the development of a Disclosure index, the degree of alignment of companies with current guidelines and regulations

Abstract (in italiano)

Questa tesi accademica si propone di analizzare la gestione e la rendicontazione dei KPI relativi alle emissioni di GHG nel panorama aziendale. Deve affrontare le normative europee, poiché con l'introduzione della nuova direttiva europea CSRD e dei suoi standard ESRS, le aziende devono ora rendicontare queste informazioni seguendo specifiche linee guida e obblighi normativi. L'attenzione, quindi, si concentrerà sulla variabilità di queste linee guida e standard e sulle metriche suggerite e su come queste possano influenzare le strategie e gli obiettivi aziendali. L'analisi empirica cercherà di comprendere come una crescente adozione di pratiche sostenibili, nonostante le differenze negli approcci e nella qualità dei dati, influenzi il monitoraggio dell'impatto, evidenziando come la contabilizzazione del carbonio non sia solo un mero requisito normativo ma un ottimo strumento per aumentare l'efficienza operativa e finanziaria. Infine, si cercherà di capire, attraverso lo sviluppo di un indice di Disclosure, il grado di allineamento delle aziende alle linee guida e alle normative vigenti.

Introduction

The climate change challenge is one of the most important and urgent issues globally, profoundly changing the surrounding environment, the economy, and people. At this juncture, companies have an important responsibility as a source of greenhouse gas emissions but also play a fundamental role in the fight against change. Emissions monitoring and reporting, therefore, are essential means of understanding, measuring, and mitigating the impacts of companies on the globe but also for achieving global sustainability goals.

Given the importance of these changes, emissions monitoring must become an integral part of companies' management control departments, as thanks to the development of well-defined KPIs, companies can identify operational inefficiencies and improve corporate transparency.

So, this thesis aims to understand how companies are adapting to the introduction of the CSRD directive, giving a detailed overview of the regulatory requirements of this directive related to greenhouse gas emissions, of the main Environmental Management Accounting (EMA) tools, also trying to understand what the state of the art of the academic literature in this regard is. Finally, it will focus on how companies monitor emissions and report them in sustainability reports through empirical analysis.

This analytical part, therefore, aims to understand what are the main guidelines and calculation methodologies that companies use, and the KPIs that are monitored through an examination of the sustainability reports of a pool of companies chosen with very specific criteria.

This thesis has been divided into 5 chapters, each dedicated to a specific issue, to provide a complete overview of current regulations and practices, including the main carbon accounting methodologies and tools, all accompanied by an empirical analysis that will aim to understand the degree of alignment of companies with them.

Specifically, the first chapter will focus on the concept of climate change, its causes and consequences. An overview of emissions trends, how they have changed over time, and their effect on the environment and society will be offered.

The second will examine the main European regulations such as the CSRD and the ESRS standards: how to apply and comply with these directives, what information needs to be reported, and how to assess their impacts, on how to monitor greenhouse gas emissions and their communication.

While the second will analyze more the legislative aspect, the third chapter will focus mainly on the tool for monitoring emissions: Environmental management accounting. How it unfolds in all its facets, and how it can be a valid resource for increasing business performance. In particular, the main MEMA and PEMA tools, such as Material Flow Cost Accounting and Lifecycle Assessment, will be analyzed and how these can be implemented in a business context.

The fourth chapter will instead be dedicated to the review of the academic literature on carbon accounting, going to find the main strands of thought in this regard, its benefits, and main limitations in the implementation of a coherent emissions management system, in particular, it will focus on the quality and variability of data and today's guidelines and standards.

The last chapter, the empirical analysis, will be based on a sample of sixty companies, chosen according to strict criteria of declared sustainability, to understand how they intend to align with today's regulations and guidelines. Specifically, the main guidelines used, the main emission calculation methodologies, and the main KPIs required by regulations and guidelines will be monitored and finally, an alignment index will be developed to understand where companies are with emissions monitoring concerning the requirements. The concrete objective of this dissertation is to assist the understanding of the strategic role of the EMA, both as a tool for European regulatory compliance and to increase business performance and mitigate the impacts of its economic activities.

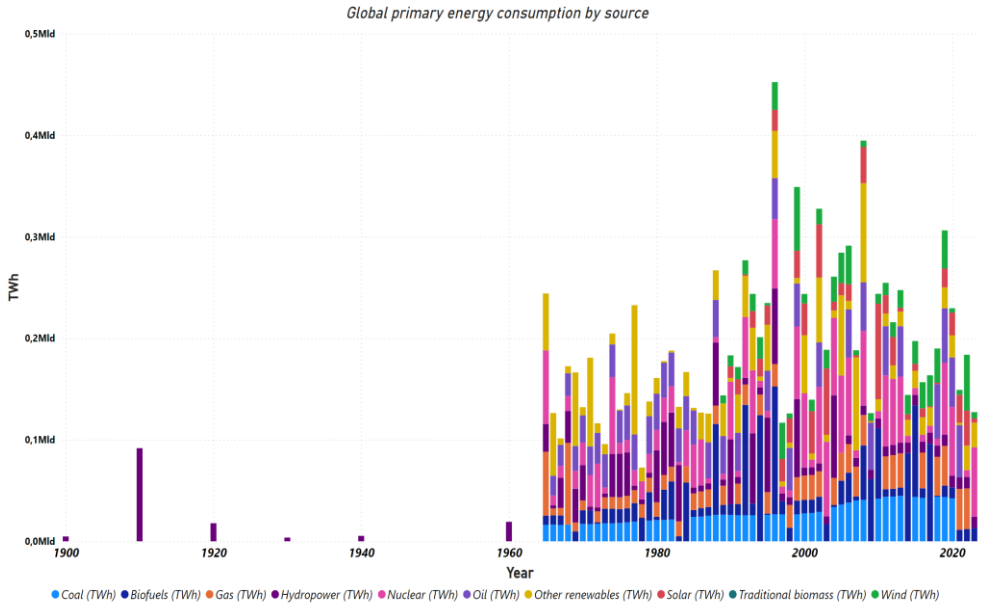
Chapter I. Climate change: Concepts and Importance

1.1. Introduction

One of the greatest and most urgent challenges of the last century that is profoundly changing the environment, economy, and society, is climate change. The planet has undergone natural changes over millions of years, but in the last century, these changes have been influenced by accelerated global warming caused by continuous growth in energy demand, the incessant production of goods and services, and an intensive consumption of the Earth's resources, such as oil and mineral resources, affecting every aspect of human life, from the smallest appearance to the largest.

As shown in the following graph (Figure 1), since the 90s, energy production has increased dramatically, from about 20,000 TWh to 180,000 TWh in 2023, releasing about 40 Gt (Gigatons) of CO2 into the atmosphere[1].

Figure 1: Global primary energy consumption by source

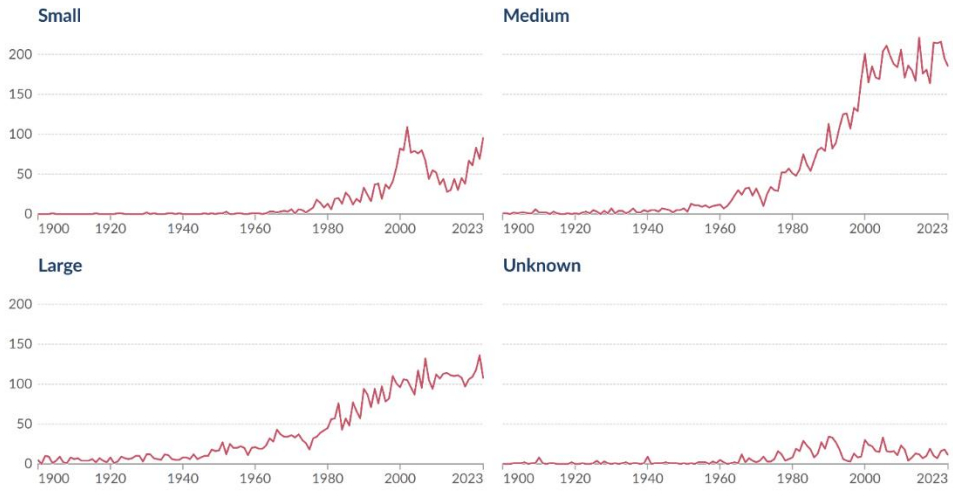


Elaboration based on: Energy Institute - Statistical Review of World Energy (2024); Smil (2017) – with major processing by Our World in Data. "Primary energy from biofuels" [dataset]. Energy Institute, "Statistical Review of World Energy"; Smil, "Energy Transitions: Global

1 https://www.energyinst.org/__data/assets/pdf_file/0006/1542714/EI_Stats_Review_2024.pdf

Human behaviors have had significant consequences on all and, over the years, have often been ignored or underestimated, but now, the effects are under the eyes of all: rising temperatures, both air and waste pollution, the melting of the polar ice caps, and meteorological catastrophes are now common news. Therefore, of fundamental importance is to find sustainable solutions for the containment and resolution of these consequences. As we can see from the image below, the number of natural disasters caused by climate change has increased dramatically in the last 40 years, both in terms of small, medium, and large-intensity natural disasters.

Figure 2: Global number of reported disasters by size, 1900 to 2023

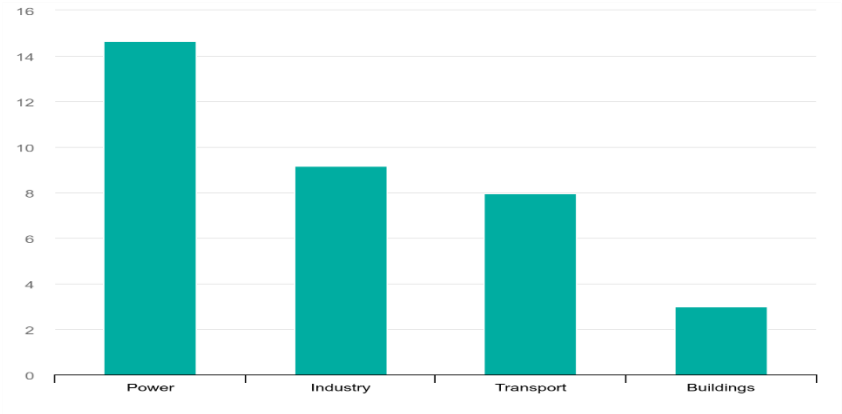


Source: EM-DAT, CRED / UCLouvain (2024) – with major processing by Our World in Data. "Number of reported natural disasters with a large impact – EM-DAT" [dataset]. EM-DAT, CRED / UCLouvain, "Natural disasters" [original data][2].

The current global energy system (Power) is the major cause of global warming, generating about 42% of the CO2 released into the atmosphere in 2022.

2 https://ourworldindata.org/natural-disasters

Figure 3: Global CO2 emissions by sector, 2019-2022



Source: IEA (2023), Global CO2 emissions by sector, 2019-2022, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-co2-emissions-by-sector-2019-2022, Licence: CC BY 4.0

Companies, institutions, and countries can understand their impacts on the environment around them through the monitoring of GHG emissions and developing more sustainable and effective strategies and practices. Furthermore, thanks to the growing environmental awareness of the stakeholders involved, such as investors and banks, this information helps to better understand the real environmental performance of companies and the policies implemented by countries.

From a business perspective, including emissions monitoring and reporting allows them to understand and translate their impacts on the environment into financial metrics and costs, and therefore the economic implications associated with emissions. These metrics also provide crucial information for investors who want to make informed investment decisions concerning environmental impacts, stimulating companies to increase their efficiency and reduce their impacts.

On the one hand, by monitoring their emissions, companies assist climate change and have a vital role in promoting zero-emission technologies and economies, on the other, by reporting, companies can develop and share increasingly new and advanced knowledge, accelerating the development and implementation of best practices and sustainable activities.

With information we help people to be more aware of their actions, starting from education in schools, awareness campaigns, and having easy and direct access to them,

which helps to increase their awareness and to be more inclined to change, supporting the adoption and promotion of more sustainable and efficient practices.

Finally, a final point to be taken into consideration and not to be underestimated in the fight against climate change is global cooperation. These challenges have no borders, they impact the whole globe and require a global effort to be at least mitigated. Through collaboration and communication, sharing information and data, more effective and efficient solutions and strategies can be created, accelerating progress toward carbon neutrality and a more sustainable and accessible world.

1.2. GHG emissions

Before moving on to the examination of emission monitoring metrics and methodologies, it is first necessary to understand what greenhouse gas emissions are and what they are, and then consequently understand the effects they have on the earth and people. The effect of greenhouse gases is to trap the heat of the sun's rays, preventing it from leaving the atmosphere, and thus warming the planet.

Many greenhouse gases are naturally present in the surrounding environment, but human activity has drastically contributed to their accumulation, causing unstable patterns of rainfall and snowfall, heat waves around the globe, droughts, and extreme weather events.

Common greenhouse gases therefore include:

- Carbon dioxide (CO2): Carbon dioxide (CO2) is produced naturally by animals during respiration and through the decomposition of biomass. It also enters the atmosphere through the combustion of fossil fuels and other chemical reactions. During photosynthesis, a process that transforms solar energy into chemical energy, plants absorb CO2 from the atmosphere. For this reason, forests are crucial for carbon sequestration.
- Methane (CH4): Methane is a colorless gas and the main component of natural gas. Its emissions come from the production and transport of coal, natural gas, and oil, as well as from agricultural activities, in particular livestock farming. Land use and the

decomposition of organic waste in municipal landfills also contribute to methane emissions.

- Nitrous oxide (N2O): This gas is generated by microbial processes in the soil, the use of nitrogen fertilizers, wood burning, and chemical production. It is emitted during agricultural and industrial activities, land use, and through the combustion of fossil fuels and solid waste. In addition, it is also released during wastewater treatment.

As far as the most harmful ones are concerned, we find the so-called fluorinated greenhouse gases:

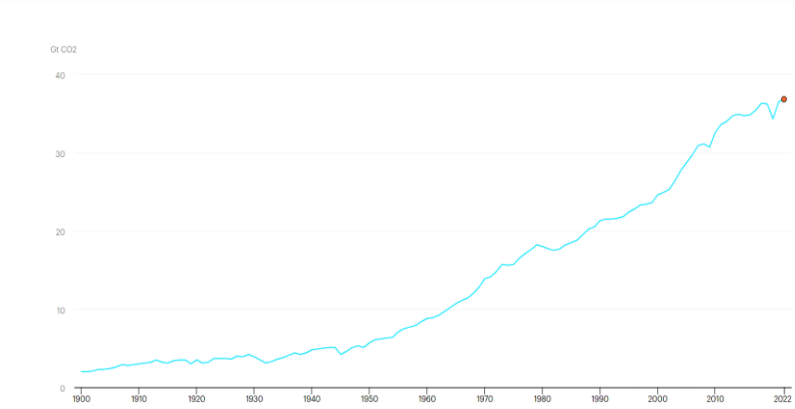
- Hydrofluorocarbons (HFCs): They are mainly used to absorb heat in refrigerators, freezers, air conditioners, and heat pumps, as well as asthma sprays and technical aerosols, foaming agents, and in fire extinguishers
- Sulphur hexafluoride (SF6): used in the insulation of power lines
- Nitrogen trifluoride (NF3) is used as a "chamber cleaning gas" in manufacturing processes to clean unwanted buildup from microprocessor parts and circuitry as they are built[3].

In any case, it must be specified that greenhouse gases have different potentials for warming the atmosphere and to be able to compare them they are converted into CO2 equivalent emitted. In 2023, energy-related emissions increased by 1.1% or about 410 million tons of CO2 equivalent (MtCO2eq.)[4]

3 https://www.europarl.europa.eu/topics/it/article/20230316STO77629/cambiamento-climatico-gas-a-effetto-serra-che-causano-il-riscaldamento-globale

4 IEA, CO2 Emissions in 2023 - A new record high, but is there light at the end of the tunnel?, 2023, https://www.iea.org/

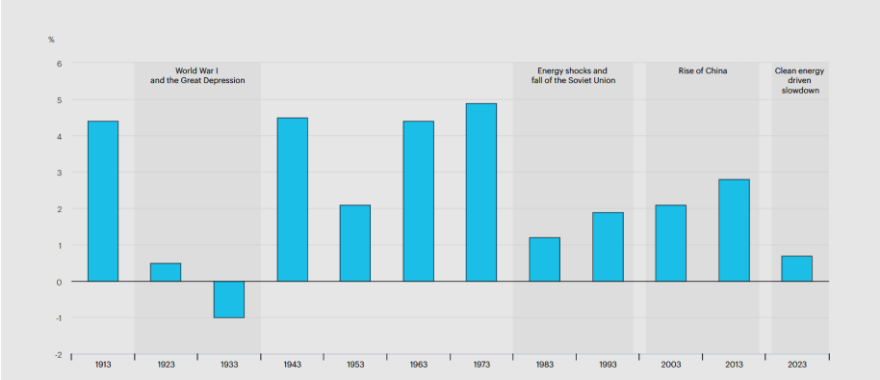
Figure 4: Total increase in energy-related CO2 emissions, 1900-2023



Source: IEA (2024), Total increase in energy-related CO2 emissions, 1900-2023, IEA, Paris https://www.iea.org/data-and-statistics/charts/total-increase-in-energy-related-co2-emissions-1900-2023, Licence: CC BY 4.0

However, over the past decade, the annual emission rate has grown more slowly than the levels of the 1970s and 1980s, indicating that the policies put in place are playing their part in the challenge of climate change.

Figure 5: Annual average rate of global CO2 emissions, 1903-2023



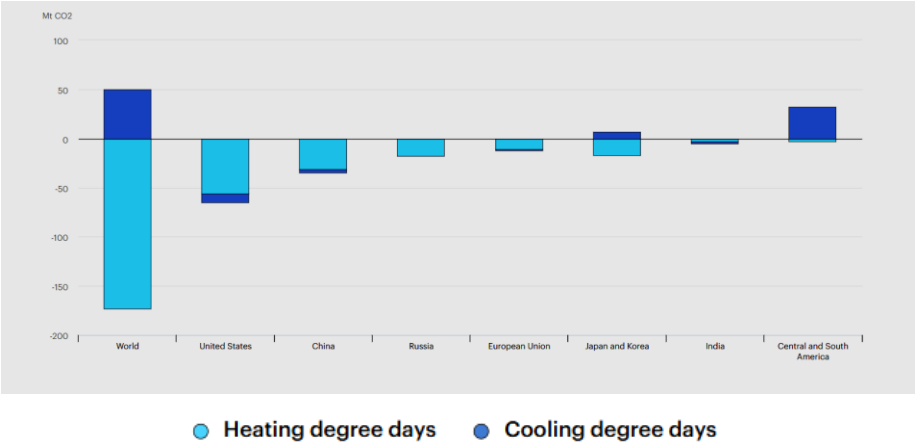
Source: IEA (2024), Annual average rate of global CO2 emissions and GDP growth by decade, 1903-2023, IEA, Paris https://www.iea.org/data-and-statistics/charts/annual-average-rate-of-global-co2-emissions-and-gdp-growth-by-decade-1903-2023, Licence: CC BY 4.0

Policies implemented in 2019, and low-emission technologies are the proponents of this slowdown, such as wind and solar energy, which saw a 75% increase compared to 2022 levels, and electric cars with 35% compared to the previous year. Between 2019 and 2023, CO2 emissions related to energy production amounted to about 900 Mt, but without

the deployment of these technologies, these emissions would have grown more than threefold.[5]

Another important aspect to consider is temperature variations: they have a big impact on the demand for energy for cooling and heating. On the one hand, 2022 and 2023 were the hottest years on record, leading to an increase in energy demand and therefore an increase in emissions, but at the same time, mild winters have offset this increase thanks to a relatively lower demand for energy for heating. Therefore, globally, emissions have seen a reduction of about 120 Mt of CO2 in 2023[6].

Figure 6: Impact of temperature variations on CO2 emissions in selected regions



Source: IEA (2024), Impact of temperature variations on CO2 emissions in selected regions, 2022-2023, IEA, Paris https://www.iea.org/data-and-statistics/charts/impact-of-temperature-variations-on-co2-emissions-in-selected-regions-2022-2023, Licence: CC BY 4.0

1.3. Net Zero

As of today, greenhouse gas emissions produced by human activities have led to a global temperature increase of about 1°C compared to pre-industrial levels. In the period 2006-2015, temperatures increased by 0.87°C compared to the pre-industrial period 1850-

5 IEA, CO2 Emissions in 2023 - A new record high, but is there light at the end of the tunnel?, 2023, https://www.iea.org/
6 IEA, CO2 Emissions in 2023 - A new record high, but is there light at the end of the tunnel?, 2023, https://www.iea.org/

1900. If continuous man-made greenhouse gas emissions continue unabated in the future, the global temperature will reach 1.5°C by 2040[7].

The response to climate change was not long in coming and thanks to a series of international policies and agreements, such as the Green Deal and the Paris Agreement, the European Union is assisting in the spread of low-emission technologies and monitoring and reporting them and therefore in their abatement by 2050.

The European Union's first step towards reducing emissions is the Green Deal: it represents a package of strategic initiatives that directs member countries towards a green transition, whose primary goal is carbon neutrality by 2050[8]. The European Commission, thanks to a series of packages, aims to implement the intentions of the Green Deal. These include:

- REPowerEU: due to the Russian invasion of Ukraine, the European Union has decided to cut relations with the invading country regarding the supply of fossil fuels. This package aims to save energy, diversify energy suppliers, and produce clean energy. By diversifying and saving energy, the EU aims to reduce dependence on Russian gas and thus ensure access for all and increase its resilience[9].
- Fit for 55: This package aims to reduce carbon emissions by 55% by 2030. This package introduces the EU ETS (Emission Trading Scheme), i.e. a scheme for trading and limiting emission allowances for energy-intensive industries and energy producers, which is the European Union's main tool for cutting emissions. The EU ETS is based on a "Cup and Trade" system, i.e. the setting of a limit of greenhouse gases that a company can emit, and this limit is reduced every year in line with EU climate targets to ensure that the target is achieved. This limit is expressed in emission permits (Emissions Allowances) and a single permit allows the company that holds it to emit one ton of CO2eq. These permits are sold through a tender (Auction) and can also be exchanged between companies. Thanks to this system,

7 IPCC, Riscaldamento globale di 1,5°C, 2018, www.sisclima.it
8 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_it
9 https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en?prefLang=it

companies must therefore monitor and report their emissions to obtain these permits and also allows them to put a price on them and thus translate them into an economic cost[10]. (At the moment the price to emit a ton of CO2eq. corresponds to 86.1€/Tco2eq.)[11]. From a short-term point of view, this system also allows households, companies, and member countries to reduce emissions cost-effectively, while in the long term, it proves to be an excellent incentive for the development of technologies and the dissemination of knowledge. Another advantage for companies comes from the fact that with the continuous increase in price and reduction of the limit, they should cut their emissions instead of buying permits. Low-emission solutions, such as LED lighting and renewable resources, make it possible to reduce the marginal costs of emissions and therefore pay less for their emissions[12].

As for the Paris Agreement, they represent a binding international treaty for the 196 countries that participated in COP 21 regarding climate change. Its goal is to contain the increase in the global average temperature to below 2° compared to pre-industrial levels and to limit it to 1.5° always compared to pre-industrial levels.

This is because, according to the IPCC[13] suggestion, exceeding the 1.5° threshold could lead to catastrophic consequences for the planet such as floods, extreme temperatures, rising sea levels, heat waves, and many other extreme weather events.

According to their report, to reduce greenhouse gas emissions they must reach their peak by 2025 and fall by 43% by 2030.

These agreements operate on a five-year cycle in which the participating countries must submit their climate action plans, the so-called Determining National Contributions (NDCs), and these plans, each five-year cycle, must reflect an increasingly ambitious

10 https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets/what-eu-ets_en?prefLang=it
11GSE, Rapporto sulle aste di quote europee di emissione – II trimestre 2023, 2023, https://www.gse.it/documenti_site/Documenti%20GSE/Rapporti%20ASTE%20CO2/Rapporto%20aste%202Q23.pdf
12 James K. Boyce, Carbon Pricing: Effectiveness and Equity, Ecological Economics, Volume 150, 2018, Pages 52-61, https://doi.org/10.1016/j.ecolecon.2018.03.030.
13 IPCC: The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change.

degree of climate neutrality ambition. In them, member countries must communicate their future actions to reduce emissions and mitigate climate change. In order to implement such actions in the long term, long-term greenhouse gas emitting development strategies (LT-LEDs) must be developed, although they are not mandatory.[14]

Therefore, it is essential to align best practices and monitoring standards globally, including at the accounting and corporate level, in order to match the efforts to achieve the goal. It is necessary to define common standards, and especially, to standardize how these are monitored. Based on these purposes, there are already European and international organizations, such as GRI (Global Reporting Initiative), the GHG Protocol, and EFRAG (European Financial Reporting Advisory Group) which outline guidelines and standards on the financial reporting of greenhouse gas emissions.

1.3.1. Tracking the energy outcomes

According to the IEA report "COP 28: tracking the energy outcomes", about 200 countries have made commitments to reduce their emissions and remain in line with the Paris Agreement goal of limiting global warming to 1.5°C. Among the actions put in place, we find doubling global energy efficiency by 2030 and tripling energy production through renewable sources, accelerating the transition to zero- or low-emission fuels. The production of electricity from renewable sources has seen a significant increase compared to the last three decades and following this trend, according to the agency, there is a real chance of being able to reach the estimated capacity by 2030.

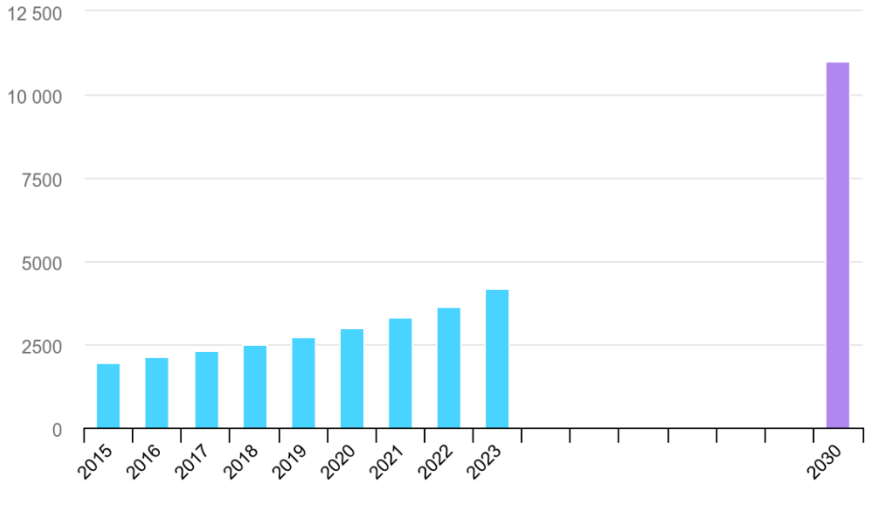
On energy efficiency, on the path to Net Zero, annual improvements must double from an annual basis of 2% to over 4% by 2030. However, according to the data collected, the current level stands at 1.1%, well below the budgeted level.

Low- and zero-emission technologies, including renewable resources, nuclear, CO2 storage technologies (CCUS), and green hydrogen, need to scale up to achieve this goal. In addition, the countries participating in COP 28 are implementing plans to reduce emissions in the road transport sector, developing low-emission infrastructure and a rapid deployment of zero- and low-emission vehicles. The electrification of the sector is one of the tools available to governments: demand for electric vehicles reached record levels in

14 https://unfccc.int/process-and-meetings/the-paris-agreement

2023 and if that demand is sustained, there will be a net cut in emissions from this sector. However, we must not forget the problem of the resources needed to build batteries, such as lithium and silicon, which are energy-intensive materials both in terms of their extraction and their disposal or recycling, when possible[15]. The road to achieving the goal is still long, but thanks to the cooperation and targeted policies, there are the conditions to be able to reduce emissions and therefore the containment of temperatures by the set date.

Figure 7: Global renewable energy capacity and COP28 pathway, 2030, IEA



Source: IEA (2024), Global renewable energy capacity and COP28 pathway, 2030, IEA, Paris https://www.iea.org/data-and-statistics/charts/global-renewable-energy-capacity-and-cop28-pathway-2030, Licence: CC BY 4.0

1.3.2. Focus on Italy:

By amending the United Nations Framework Convention on Climate Change (UNFCCC) and being in line with the commitments made under the Paris Agreement, Italy, like the other signatory countries, must monitor and transmit the national inventory of greenhouse gases. Issued by ISPRA[16], it must contain tables of greenhouse gases with time series since 1990, activity data, emission factors used, and emissions by sector and LULUCF[17].

15 https://www.iea.org/topics/cop28-tracking-the-energy-outcomes
16 ISPRA (Istituto Superiore per la Protezione e la Ricerca Ambientale): The ISPRA is a public research body, with legal personality under public law, technical, scientific, organizational, financial, managerial, administrative, patrimonial, and accounting autonomy.
17 LULUCF: Land Use, Land Use Change and Forestry

The national inventory estimates emissions from several sectors:

- energy
- Industrial processes and use of products (IPPUs)
- agriculture
- waste and removals and greenhouse gas emissions for the LULUCF sector

Figure 8: GHG Emission of Italy

Emissioni GHG	1990	1995	2000	2005	2010	2015	2019	2020	2021	2022
					kt CO_2 equivalente					
CO_2 escluso LULUCF	438,208	448,596	469,598	501,366	435,701	361,246	339,641	302,614	335,920	340,904
CO_2 incluso LULUCF	432,937	424,242	448,286	466,925	395,419	318,828	301,380	274,409	310,024	318,796
CH_4 escluso LULUCF	54,971	57,026	57,698	54,806	52,874	49,370	46,685	47,402	47,036	45,714
CH_4 incluso LULUCF	55,691	57,196	58,098	54,973	53,071	49,518	46,787	47,588	47,525	46,072
N_2O escluso LULUCF	24,475	26,416	27,183	26,337	18,305	17,101	16,897	17,570	17,457	15,738
N_2O incluso LULUCF	25,383	27,212	27,872	26,925	18,707	17,436	17,354	18,090	18,076	16,288
HFCs	372	1,100	3,747	9,666	12,805	12,082	11,089	9,971	9,411	9,085
PFCs	2,615	1,351	1,363	1,759	1,377	1,529	915	499	395	439
Mix di HFCs e PFCs	NO,NA	24	24	24	24	24	23	22	25	22
SF_6	421	700	621	565	405	483	438	252	282	390
NF_3	NA,NO	77	13	33	20	28	18	16	15	20
CO_2 indirette	1,311	1,211	1,073	1,041	860	692	786	705	740	728
Totale (senza LULUCF)*	**522,373**	**536,500**	**561,322**	**595,598**	**522,371**	**442,557**	**416,493**	**379,051**	**411,282**	**413,041**
Totale (con LULUCF)*	**518,730**	**513,112**	**541,099**	**561,913**	**482,687**	**400,621**	**378,791**	**351,552**	**386,495**	**391,842**

Settori	1990	1995	2000	2005	2010	2015	2019	2020	2021	2022
					kt CO_2 equivalente					
1. Energia	426,167	438,670	460,484	488,344	429,916	359,981	336,404	300,064	332,164	337,877
2. Processi Industriali ed Uso dei Prodotti	37,946	36,299	38,240	47,132	36,591	29,094	27,330	24,290	25,300	23,620
3. Agricoltura	37,953	38,312	37,430	35,028	32,634	32,455	32,314	33,534	32,862	30,764
4. LULUCF	-3,643	-23,388	-20,223	-33,685	-39,684	-41,935	-37,702	-27,499	-24,787	-21,199
5. Rifiuti	18,996	22,008	24,094	24,052	22,371	20,334	19,659	20,458	20,215	20,052
CO_2 indirette	1,311	1,211	1,073	1,041	860	692	786	705	740	728
Totale (con LULUCF)*	**518,730**	**513,112**	**541,099**	**561,913**	**482,687**	**400,621**	**378,791**	**351,552**	**386,495**	**391,842**

** Le emissioni totali includono le emissioni indirette di CO_2*

Source: https://www.isprambiente.gov.it/files2024/pubblicazioni/rapporti/rapporto-399-24-le-emissioni-di-gas-serra-in-italia.pdf

In light of the report published by ISPRA on 1990-2022 data, Italian emissions fell by 20.9% in the period under review. This reduction was driven by a decrease in energy consumption and industrial production caused by the economic crisis of 2008 and the relocation of industrial production plants (obviously also due to the pandemic) but also thanks to the spread and growth of renewable sources. As seen from the table, in the period under review, emissions went from 522 million tons of CO2 equivalent to a value of 413 million tons eq. in 2022.

The sector that produces the most greenhouse gas emissions is energy, which accounts for 81.8% in 2022. But the figure is encouraging, recording a decrease of 20.7% compared to 1990 levels. As for the other sectors, the transport sector produced about

26.6% of the total and recorded an increase of 7.4% from 1990 to 2022. However, the other sectors examined achieved significant decreases in terms of emissions[18].

18 ISPRA, Le emissioni di gas serra in Italia. Obbiettivo di riduzione al 2030, 2024, https://www.isprambiente.gov.it/files2024/pubblicazioni/rapporti/rapporto-399-24-le-emissioni-di-gas-serra-in-italia.pdf

Chapter II. Sustainability Compliance: European Guidelines and Reporting Obligations

2.1. The introduction of European Sustainability Reporting Standards (Commission Delegated Regulation (EU) 2023/2772)

In recent years, a growing awareness of sustainability has been a major priority in economic and political strategies worldwide. The European Union has become a key pillar in promoting green initiatives aimed at energy transition and social responsibility, undertaking reforms to integrate environmental, social, and governance (ESG) criteria into economic activities. One example of these efforts is the new Corporate Sustainability Reporting Directive (CSRD) 2022/2464, which came into force on 1 January 2024 and fills some regulatory gaps in the previous directive, Directive 2014/95 (NFRD). It ensures better consistency and comparability of non-financial data reported by companies.

The pivot of this directive is the European Sustainability Reporting Standards (ESRS), which implement the criteria for reporting on environmental, social, and governance issues. They define the information companies must mandatorily monitor and report to enable stakeholders to understand the impacts, risks, and opportunities related to social sustainability, energy transition, and climate change. One of the main objectives of the CSRD directive is to provide investors and other stakeholders with reliable and comparable information, thus introducing mandatory verification of reported information by external auditors, thereby ensuring the credibility of the data.

The adoption of these practices for reporting on the non-financial performance of companies was an important step towards achieving the social and environmental objectives of the European Union and the Paris Agreements.

With the directive 2023/2772 (ESRS), the European Union aims to define sustainability reporting principles. It applies:

- Large companies: companies with more than 250 employees, a net turnover of more than 40 million euros, or a balance sheet of more than 20 million euros (including public ones).

- Listed companies: companies listed on EU-regulated markets must draw up the non-financial sustainability statement
- Listed small and medium-sized companies: they are subject to a simplified version of the ESRS standards (reporting obligation from 1 January 2026).
- Non-EU companies with a significant presence and business in the EU-regulated market.

The purpose of the ESRS reporting principles is to define the necessary sustainability information that a company must disclose to be compliant with the directive 2022/2464 (CSRD) (there are also other standards or principles defined by other bodies that are under this directive). In particular, the ESRS principles, built under a European Union mandate by EFRAG, the European Financial Reporting Advisory Group, identify the information that a company *must disclose regarding its substantial impacts, risks, and opportunities regarding environmental, social, and governance sustainability issues. They must enable users to understand the significant impacts of the company on people and the environment and the relevant effects of sustainability issues on the development, results, and situation of the company*[1].

2.1.1. General Principles

The sustainability statement is specific to the reporting entity. For example, if the reporting entity is a parent company required to prepare consolidated financial statements, the sustainability statement will cover the entire group.

The information provided in the sustainability statement extends beyond the reporting entity itself, including data on relevant impacts, risks, and opportunities related to the company through its direct and indirect business relationships in the value chain, both upstream and downstream. In other words, the company must consider the entire value chain when assessing sustainability, including suppliers (upstream) and customers or distributors (downstream). However, this extension of information is based on the results of the due diligence process and materiality assessment. It must comply with any specific requirements set by other ESRS standards related to the value chain.

1 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

However, reporting detailed information on each actor in the value chain is not mandatory. The company must only include information on the value chain concerning those actors and parts of the process that are relevant in terms of sustainability. This means that different sustainability issues may be relevant to different parts of the value chain, both upstream and downstream of the company.

Value chain information must be provided when necessary to enable the report's users to understand the impacts, risks, and opportunities relevant to the company or to ensure that the set of information provided meets the required quality characteristics, as defined in the guidelines. In identifying the level at which a sustainability issue becomes material, both in the company's operations and along the value chain, the company should base its assessment of impacts, risks, and opportunities on its evaluation, applying the principle of double materiality.

When associates or joint ventures, whether accounted for using the equity method or consolidated in the financial statements using the proportionate method, are part of the value chain, for example in the role of suppliers, the company must include information about these associates or joint ventures, by the approach taken for other business relationships. In these cases, when determining impact metrics, the company does not merely consider its ownership share in such entities. Still, it thinks the overall impacts related to the products and services offered through the business relationships.

Going into detail on the ESRS principles, three categories of ESRS principles have been prepared:

1) Cross-cutting Standards
2) Topical Standards (environmental, social, and governance)
3) Sector-specific Standards

The Cross-cutting Standards provide the basic guidelines for all obliged companies. They apply regardless of the relevant economic sector and are designed to ensure that the statement is consistent, complete, and qualitative. Among the most fundamental ones is the principle of Dual Materiality: this principle has two dimensions, impact relevance and financial relevance. These two dimensions are interconnected: *a sustainability impact can be financially material from the outset or become financially significant when it can*

reasonably be expected to affect the financial position. A sustainability issue *becomes relevant when it concerns the significant impacts of the company, negative or positive, actual or potential, on people or the environment in the short, medium, and long term. Impacts include those related to the company's operations and upstream and downstream value chain, including through its products and services and its business relationships.* In addition, companies must submit plans or actions to mitigate or cancel the impact, or to exploit an opportunity consistently, clearly, and transparently[2].

Moving on to the Topical Standards, they are divided into three sub-principles:

- Environmental Principles: these refer to impacts on the environment, climate change, biodiversity, efficient use of resources, and finally the circular economy. Companies must report how and to what extent their activities impact these areas.
- Social Principles: Companies must provide information on human rights, working conditions, gender equality, diversity, and inclusion.
- Governance Principles: refer to ethics, transparency in the information communicated, organizational structure, business processes, and decisions to ensure that sustainability strategies are pursued and supported.

The last principle, the Sector-specific one, provides specific guidelines for different economic sectors. However, EFRAG still reviewing and defining these standards[3].

The Scope of Reporting and Minimum Disclosure Requirements for Content on Policies, Actions, Objectives, and Metrics are governed by ESRS Principle 2 and relate specifically to thematic and sectoral principles. Information and data on processes, governance controls (GOV) used to monitor impacts risks, and opportunities (IROs) must be reported. By impacts, this refers to positive or negative impacts related to sustainability, and by risks and opportunities, to financial risks and opportunities also related to sustainability. The company, therefore, must state the processes by which IROs

2 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772
3 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

are monitored, as well as how sustainability issues are managed with policies and actions, and finally the metrics used and targets (MT) set[4].

In presenting information, companies must consider the past, present, and future, explaining the initial situation (the base year) and the progress achieved by the strategies implemented. Thus, when preparing sustainability reports, they must consider time intervals consistent with those of the directive, namely:

- The short-term time horizon: consistent with the reference period of its financial statements.
- The medium-term time horizon: up to five years.
- The long-term time horizon: beyond five years.

Finally, the information delivered must meet established quality standards. To get started, it must be relevant, which means it must comply with the concept of dual materiality by being meaningful to both the organization and its stakeholders. Furthermore, this information must provide feedback on previous data, highlighting changes in either positive or negative terms.

Another important consideration is faithful representation: the provided data must adequately reflect the phenomenon in its entirety. This requires that the information be comprehensive, neutral, and accurate.

Comparability is another important need. The information must be comparable not only to past periods but also to data from other companies, ensuring a consistent frame of reference.

Furthermore, verifiability is critical: facts must be able to be reviewed and validated. To verify its comprehensiveness, neutrality, and accuracy, it should be examined as a whole, as well as in its sources.

Finally, information must be presented in an accessible format. Clear language is required, especially the avoidance of generic or stereotypical terms. The goal is to develop a

4 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

consistent information system that people can easily understand without ambiguity or uncertainty[5].

2.2.2. Monitoring GHG Emissions

Concerning the monitoring and reporting of greenhouse gas emissions, with the ESRS E1 (European Sustainability Reporting Standard E1) standard, the EU aims to define the requirements for reporting the information that companies must disclose on climate change.

The aim is to train companies to report on their performance and impacts related to climate change. In particular, companies must report how their activities impact, positively or negatively, effectively or potentially, on climate change. This includes providing details about past, present, and future actions that align with the Paris Agreement, which aims to limit the global average temperature increase to 1.5°C compared to pre-industrial levels. Companies must disclose their emissions of the seven greenhouse gases, such as carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (CHC), perfluorocarbons (PFCs), sulfur hexafluoride (SF6), and nitrogen trifluoride (NF3).

Additionally, companies must report on the nature, type, and extent of risks and opportunities stemming from their actions, as well as their dependencies on climate change. This should also include an assessment of potential "locked-in" greenhouse gas emissions from the company's key products and assets, with explanations of how these emissions could jeopardize the achievement of transition goals. Furthermore, companies must outline the short, medium, and long-term financial consequences of the risks and opportunities related to climate change. They are also required to report their emissions into the atmosphere of Ozone-Depleting Substances, such as nitrogen oxides (NOX) and sulfur oxides (SOX)[6].

In establishing the strategies to be adopted, the interested parties must be informed of the objectives and metrics used for climate change mitigation. Therefore, the company

5 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772
6 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

must disclose how it has set emission reduction targets and how it wants to manage climate-related impacts, risks, and opportunities.

The reduction targets must be communicated as an absolute value in tons of CO2eq or as a percentage of the emissions of a base year and also the emission intensity of these emissions[7].

In order to monitor GHG emissions, companies must first define organizational boundaries: which activities, entities, and business operations should be included in the emissions calculation based on the control the company has over those activities. Next, it needs to establish what the operational boundaries are, identify emissions based on your operations, divide them into direct and indirect emissions, and finally agree on which accounting and reporting area they belong to. Setting operational boundaries, which include both direct and indirect boundaries, allows companies to better manage the broad spectrum of risks and opportunities of their emissions throughout their value chain. Therefore, direct emissions can be defined as emissions from sources that are under the control of the company, while indirect emissions include those that result from the company's activities but are released into the atmosphere by another entity or source owned or controlled by the company. In addition, by defining the purpose, companies can better delineate which are direct and indirect, improving transparency and understanding by the stakeholders involved and policymakers[8].

Emissions, therefore, must be specified whether they are scope 1, 2, or 3, separately or in combination. The calculation must be done grossly, so greenhouse gas absorptions, carbon credits, and avoided emissions must be excluded. The last step is the monitoring and reporting of total greenhouse gas emissions.

As regards emission Scope 1, 2, and 3:

1) Scope 1 gross greenhouse gas emissions: these relate to the company's direct impacts on climate change and the percentage of its total emissions regulated by emissions trading schemes. Must calculate greenhouse gas emissions from stationary, mobile, process emissions, and fugitive emissions.

7 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772
8 https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

2) Scope 2 gross greenhouse gas emissions: related to the indirect impacts on climate change generated by the energy consumed by the company, both acquired and purchased externally. For the calculation, must be applied the position-based and market-based methods. The first quantifies scope 2 emissions based on the average emission factors of energy production for defined locations. While market-based emissions quantify emissions based on those of the producers from whom the company buys energy.
3) Scope 3 gross greenhouse gas emissions: correspond to emissions generated along the upstream and downstream value chain, in addition to those of scope 1 and 2. It must identify significant Scope 3 categories based on the magnitude of its estimated emissions, applying the correct emission factors. For each category identified, the reporting perimeter considered, and the calculation methods and tools used must be provided[9].

Finally, for the calculation of total emissions, companies can apply the following formulas:

$$Total\ Location-based\ GHG\ emissions\ (tCO2eq)\ =\ gross\ scope\ 1\ +\ gross\ scope\ 2\ position-based\ +\ gross\ scope\ 3$$

$$Total\ Market-based\ GHG\ emissions\ (tCO2eq)\ =\ gross\ scope\ 1\ +\ gross\ scope\ 2\ market-based\ +\ gross\ scope\ 3$$

The company can report its total greenhouse gas emissions disaggregated by scope 1 and 2 and for significant scope 3 categories as in the following table.

9 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

Figure 9: example of how total GHG emissions data should be presented

	Retrospective					Milestones and target years			
	Base year	Comparative data	N	%N/N-1		2025	2030	(2050)	Annual % target / Base year
Scope 1 GHG emissions									
Scope 1 gross GHG emissions (tCO2eq)									
Share of Scope 1 GHG emissions covered by Regulated Emissions Trading Systems (%)									
Scope 2 GHG emissions									
Location-based Scope 2 gross GHG emissions (tCO2eq)									
market-based gross Scope 2 GHG emissions (tCO2eq)									
Significant Scope 3 GHG emissions									
Scope 3 gross indirect GHG emissions (tCO2eq)									
Goods and services purchased									
Optional Subcategory: Cloud Computing and Data Center Services									
Goods									
Fuel and energy-related activities (not included in scope 1 and 2)									
Upstream transport and distribution									
Waste from operations									
Business Travel									
Employee commuting									
Upstream leasing activities									
Downstream transport									
Processing of products sold									
Use of products sold									
End-of-life treatment of products sold									
Downstream leasing activities									
Franchising									
Investments									
Total GHG emissions									
Total GHG emissions (based on location) (tCO2eq)									
Total GHG emissions (market-based) (tCO2eq)									

Elaboration based on: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

To highlight possible transition risks, they can disaggregate their total emissions by significant country, and where appropriate, by operating sector.

In preparing the information for monitoring and reporting emissions, the company must take into consideration the principles, requirements, and guidelines of the Corporate Accounting and Reporting Standard of the Greenhouse Gas Protocol, indicating the calculation methodology, the assumptions and emission factors used, and the reasons for the choice, and in the case of using online tools for the calculation, the link to the tool used must be provided[10].

One critical aspect of GHG reporting is the measurement of emissions intensity, an indicator that measures the amount of GHG emissions released per unit of economic activity or production. This metric is essential for evaluating the efficiency of an organization in managing its emissions relative to its financial performance.

This Directive suggests that intensity should be calculated based on net revenues:

$$GHG\ EMISSIONS\ INTENISITY = Total\ Greenhouse\ gas\ emissions\ (tCO2eq) / Net\ Income\ (monetary\ unit)$$

10 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

Net Income should be calculated in line with accounting standards, in particular IFRS 15 Revenue from Contracts with Customers or local GAAP. [11] This method enables stakeholders to evaluate how well a company manages its emissions about its economic output, enabling more accountability and comparability in sustainability reporting.

The results can be presented through a table, as in the following one, separating the emissions based on the position and market method:

Figure 10: example of how GHG emission Intensity data should be presented

GHG INTENSITY BASED ON NET INCOME	Comparative data	N	%N/N-1
Total GHG Emissions (Location-based) based on Net Income (tCO2eq/monetary unit)			
Total GHG Emissions (Market-based) based on Net Income (tCO2eq/monetary unit)			

Elaboration based on: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

11 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

2.2.3. GHG removals

Outside of their greenhouse gas emission inventories, companies must ensure transparency throughout the value chain on how and how much they improve natural sinks or implement solutions to absorb the greenhouse gases of their operations.

Figure 11: Carbon capture & storage plant located in Iceland

Source: https://www.technologyreview.com/2022/04/04/1048832/un-climate-report-carbon-removal-is-now-essential/

Therefore, the company must indicate:

- The greenhouse gases absorbed
- Whether the uptake and storage are biogenic or through land use change *(e.g. afforestation, reforestation, forest restoration, urban greening, agroforestry, increased soil carbon, etc.),* technological *(direct atmospheric capture) or* hybrid *(bioenergy with CO2 capture and storage),* mentioning in detail the absorption technology, type of storage, if necessary, the type of transport of the absorbed greenhouse gases.
- Whether the activity qualifies as a nature-based solution and how the risk of non-permanence is managed[12].

12 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

When monitoring and reporting information, companies must rely on the principles of the GHG Protocol, in particular:

- *Corporate Accounting and Reporting Standard* (version 2004).
- *Product Life Cycle Accounting and Reporting Standard* (version 2011).
- *Agriculture Guidance* (2014 version).
- *Land Use, Land-Use Change, and Forestry Guidance for GHG Project Accounting* (version 2006)[13].

Finally, the information on greenhouse gas removals can be shown in the form of a table, as follows:

Figure 12: Example of how GHG absorption data should be presented

Absorption	Comparative Data	N	%N/N-1
GHG 1 absorption activities (e.g. forest restoration)			
GHG 2 absorption activity (e.g. direct capture from the atmosphere)			
Total GHG removals in own operations (tCO2eq)			
GHG 1 absorption activities (e.g. forest restoration)			
GHG absorption activity 2 (e.g. direct capture from the atmosphere)			
…			
Total GHG removals along the upstream and downstream value chain (tCO2eq)			
Inversions (tCO2eq)			

Elaboration based on: https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

2.2.4. Significant expected transitional financial effects

Material climate-related transition risks could affect the company's financial position, results of operations, and cash flows.

However, until today, there is still not commonly accepted and used methodology to monitor the effects of transition risks. In any case, the company must communicate how:

- Assessed the possible effects on future economic and financial results related to corporate activities, including the scope of application, methodologies, and assumptions.

13 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

- It must also define and explain the time horizons considered
- When assessing potential future liabilities, undertakings may consider and disclose the number of Scope 1 emission allowances in regulated emissions trading systems and the number of allowances at the beginning of the reporting period.

In reporting on the costs and risks of climate transition, the GHG Protocol has released a calculation guideline incorporated into the CSRD to assign a monetary value to emissions based on the market price of emission allowances or other methodologies based on the social costs of carbon. Such methodologies based on the social costs of carbon refer for example to the internal price of carbon, which is a tool used by companies and organizations to track environmental greenhouse gas emissions in business decisions and strategies. It consists of an estimate of the cost of CO2 emissions in such a way that it results as a tax or a common operating cost. Commonly this estimate is made in €/mtCO2eq[14]. This internal carbon price can be understood as a Pigouvian tax; Therefore, the cost per tonne of GHG emitted corresponds exactly to an increase in the damage attributed.

There are various forms of internal carbon pricing, the main ones being:

- Shadow Prices: this allows investments and assets to be evaluated by including a pre-established price for the CO2 emitted. The aim is to understand how future external carbon prices impact investment returns. In a nutshell, therefore, it represents a hypothesis on a key future aspect considered during the evaluation of investments (no monetary value is moved). As a starting point for defining a Shadow price, the implicit carbon price is usually used, which is deducted from the costs incurred by a company to implement its reduction plans.
- Internal carbon fees: this is a tax that society imposes on itself for the tons of CO2 emitted. It can be based on a shadow price or on the cost of emission abatement (MAC[15])[16].

14 https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf
15 MAC (Marginal Abatement Cost): it is an economic and analytical tool used to assess the cost of reducing greenhouse gas (GHG) emissions per unit reduction (usually expressed in tons of CO_2 equivalent)
16 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

KPMG, in its report *How to get an internal carbon pricing right*, provides detailed guidelines on how to properly implement an internal carbon pricing. The first step is to define the objectives of the implementation of the internal carbon price. This requires an analysis of current regulations, the setting of emission reduction targets, and the selection of relevant information to consider. Next, it is important to understand how already regulated prices, such as the EU ETS (European Union Emissions Trading System), can impact the company. This includes mapping out key regulated prices and conducting a scenario analysis to understand how the company could be involved in a regulated carbon pricing system, both in the short and long term. The third step concerns the estimation of the internal price of carbon. Once the above steps have been completed, the best method of setting this price is determined through external research on the marginal cost of abatement (MAC) related to the company's activities. For example, a tax could be set for the use of electricity equal to the amount that would have to be paid for equivalent renewable energy certificates. It is then necessary to calculate the company's marginal cost of abatement (MACC) curve, evaluate future carbon pricing scenarios, and select a price that is in line with the targets set. Once you've defined the price, it's a good idea to conduct a pilot to test its effectiveness. This includes a financial analysis of how an internal carbon price might affect investment planning, through the use of shadow pricing, or attract funds for sustainable initiatives through an internal fee. Finally, the company is expected to develop a long-term roadmap for carbon pricing. This involves assessing the organizational impacts of implementing the strategy, developing a communication and engagement plan, integrating carbon pricing into business operations, and constantly monitoring the process to make any adjustments[17].

Therefore, following the guidelines of the GHG Protocol, it is possible to define the monetary value of one's gross greenhouse gas emissions, both Scope 1 and 2, and total, as follows:

- $Gross\ Scope\ 1\ Greenhouse\ Gas\ Emissions\ (tCO2eq)\ +$
  $Scope\ 2\ Greenhouse\ Gas\ Emissions\ (tCO2eq)\ X\ Cost\ Coefficient\ of\ Greenhouse\ Gas\ Emissions\ (€/tCO2eq),$

17 KPMG, How to get internal carbon pricing right,https://kpmg.com/kpmgus/content/dam/kpmg/pdf/2023/how-to-get-internal-carbon-pricing-right.pdf

or:

- $Total\ greenhouse\ gas\ emissions\ (tCO2eq) X\ Cost\ coefficient\ of\ greenhouse\ gas\ emissions\ \left(\frac{€}{tCO2eq}\right)$

For the cost coefficient of greenhouse gas emissions (€/tCO2eq), the market price of Emission allowances or the internal carbon pricing can be used, explaining the reasons for this choice[18].

18 REGOLAMENTO DELEGATO (UE) 2023/2772 DELLA COMMISSIONE (ESRS), UE Commission, 2023, https://eur-lex.europa.eu/legal-content/IT/TXT/?uri=OJ%3AL_202302772

Chapter III. Environmental Management Accounting (EMA)

3.1. The definition and importance of EMA

The increasing magnitude of climate change's effects and people's and companies' awareness of the impacts of their actions on the planet has led to a change in the vision and approach of business practices. Environmental risks are now considered in investment valuations, they influence companies' image, and their management is taken into account by the banking system when it comes to a company's credit rating.

By integrating environmental factors into accounting processes, managers can be aware of and better manage environmental costs. Often, these costs are underestimated or not considered at all (Sunk Costs), and once they occur, finding solutions to limit their negative effects both externally and internally is almost impossible. Most conventional accounting systems are not able to handle such costs, and consequently, they are classified as overhead costs or not even considered.

EMA helps management to identify the information needed to improve environmental performance. From a classical accounting point of view, it can be considered a mix of cost and financial accounting methodologies built to minimize environmental impact, manage risks, and reduce costs[19].

It can be seen as a collection of internal efforts to formally articulate environmental goals, make choices that integrate the environment into production decisions, identify opportunities to reduce emissions and implement plans to make continuous improvements in production and environmental performance. Numerous standards have been developed to support organizations in developing an EMA system: like ISO 14001, the United Kingdom, in 1996, launched the Eco-Management and Audit Scheme (EMAS III), later adopted by the European Union with an ad hoc regulation[20].

19 Hasan et al., (2024). Innovating for Sustainability: the role of environmental management accounting in driving Environmental performance. Discover Sustainability, Volume 5, article number 183, page 3
20 Thanh Nguyet Phan et al. (2017), The use and effectiveness of environmental management accounting, Australasian Journal of Environmental Management, Volume 24, issue 4, page 5

This scheme helps companies to improve environmental aspects through compliance with current standards on environmental issues as well as its continuous improvement and provide information to all stakeholders[21].

The development of EMA has also been supported by numerous international governmental bodies, evidenced through numerous publications of various documents and guidelines, such as *the International Guidance Document: EMA' by the International Federation of Accountants, the EMA Workbook by the Japanese Ministry of Economy, Trade and Industry*. However, the growth in the use of EMA has been relatively slow, with many organizations only minimally applying the potential of a well-structured EMA system[22].

Over the years, scholars have also investigated the relationship between Environmental Management Accounting and a company's environmental performance: the results show that there is a positive correlation between them. Furthermore, it has been shown that by safeguarding the natural environment, interconnecting EMA with production capacities, information technology, as well as management and accounting knowledge, it is possible to develop new, more efficient, and innovative products and services[23].

This practice provides important information on the life cycle of a product, which in turn can be improved and monitored. Companies having systems in place that generate social and environmental data have more robust internal control structures that allow them to make better-informed decisions and strategies. Companies benefit from innovation, offering a competitive advantage in the marketplace, the use of EMA only amplifies the effects, improving company performance and in turn stimulating innovation in a virtuous circle[24].

21 Thanh Nguyet Phan et al. (2017), The use and effectiveness of environmental management accounting, Australasian Journal of Environmental Management, Volume 24, issue 4, page 5
22 Thanh Nguyet Phan, Kevin Baird & Sophia Su, The use and effectiveness of environmental management accounting, 2017, Australasian Journal of Environmental Management, Volume 24, issue 4, page 5
23 Hasan et al., (2024). Innovating for Sustainability: the role of environmental management accounting in driving Environmental performance. Discover Sustainability, Volume 5, article number 183, page 5
24 Hasan et al., (2024). Innovating for Sustainability: the role of environmental management accounting in driving Environmental performance. Discover Sustainability, Volume 5, article number 183, page 3

Costs related to a company's environmental impacts play a very significant role in a company's total operating costs, and the EMA system provides important physical and monetary environmental information that can greatly influence economic and environmental performance.

By implementing a cost allocation system, this information can be used to understand where the organization's impacts occur and thus support long-term sustainable growth[25].

We must not forget the role of top management, which plays a fundamental role in the adoption of innovative practices, providing leadership, training, and a direct line to employees, facilitating their involvement in the adoption of sustainable practices. Such involvement is crucial if an efficient and sustainable system is to be built[26].

It is not a stand-alone system, but rather complementary or ancillary to the traditional accounting approach, which aids the identification and allocation of costs associated with the environment. The main areas of application of EMA are as varied as product pricing, budgeting, investment and project evaluation, cost monitoring and reporting, and finally KPI setting[27].

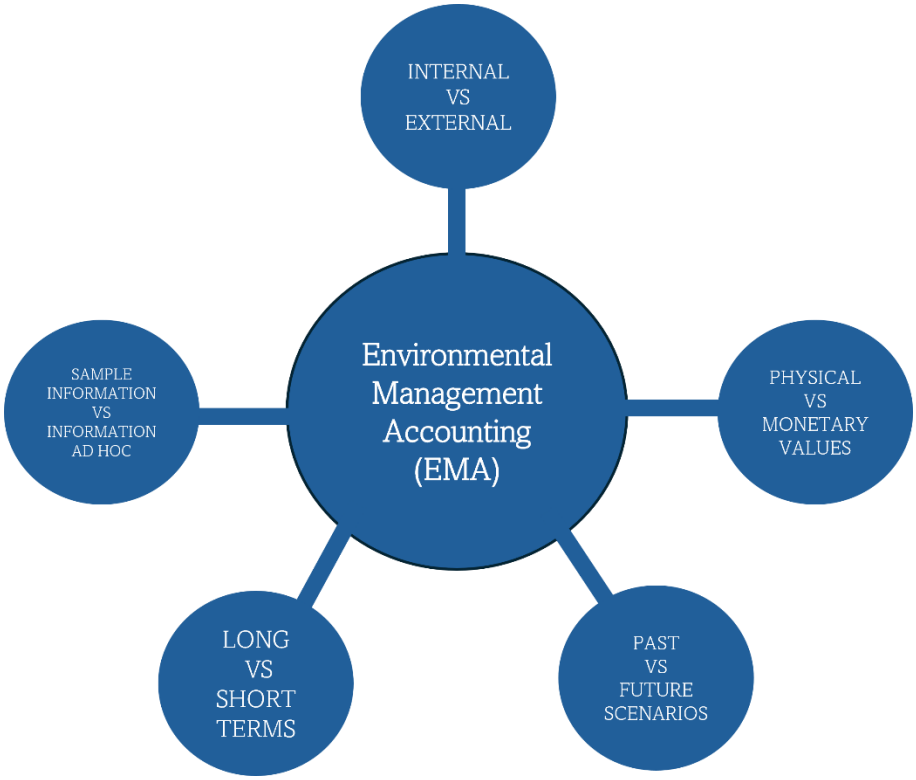
Burritt et al. (2002), in their studies, developed a multidimensional framework based on five fundamental dimensions. This framework offers guidance for applying different Environmental Management Accounting (EMA) techniques, such as Lifecycle Assessment[28] and Environmental Cost Accounting. The dimensions identified by the scholars are internal versus external, which distinguishes between relevant environmental aspects within the organization and those related to the external context. Physical versus monetary, which involves the collection of physical data, such as emissions or resource consumption, versus their quantification in monetary terms.

25 Thanh Nguyet Phan et al. (2017), The use and effectiveness of environmental management accounting, Australasian Journal of Environmental Management, Volume 24, issue 4, page 5
26 Thanh Nguyet Phan et al. (2017), The use and effectiveness of environmental management accounting, Australasian Journal of Environmental Management, Volume 24, issue 4, page 4
27 Roger L. Burritt et al. (2002), Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2, page 4
28 Life Cycle Assessment (LCA), or Life Cycle Analysis, is a structured and systematic methodology used to assess the environmental impacts associated with all phases of the life cycle of a product, process, or service.

The third dimension is based on past and future scenarios, which make it possible to monitor and analyse both historical data and future projections and thus also short and long-term time horizons.

Finally, the collection of ad hoc information as opposed to the classical information of traditional accounting systems highlights how data can be collected specifically for particular needs or derived from pre-existing accounting structures[29].

Figure 13: The multidimensional EMA framework based on five fundamental dimensions



To fully understand what Environmental Management Accounting (EMA) is, it must be explained that there are two major groups of environmental impacts related to a company's activities:

1) Environmental impacts of a particular economic situation on the company.
2) The environmental impacts caused by the company's economic activities on the surrounding environment.

29 https://www.accaglobal.com/uk/en/student/exam-support-resources/professional-exams-study-resources/p5/technical-articles/environmenta-management.html

Impacts of the first group refer to their consequences in monetary terms on society, i.e., monetary environmental information refers to all impacts of the company on past, present, or future stocks and cash flows expressed in monetary units. While the impacts of the second group on the physical environment, specifically, past, present, and future information on the amount of material and energy impacting the environment. This information is usually expressed in kilograms, cubic meters, KWh, or MWh (e.g. kilograms of material per customer served, MW of energy used per unit of product). These two dimensions taken together make up the broader concept of Environmental Management Accounting[30].

These two dimensions are referred to in academic language as Monetary Environmental Management Accounting (MEMA) and Physical Environmental Management Accounting (PEMA).

In detail, MEMA is based on conventional Management Accounting but is extended and designed to monitor environmental aspects. It contributes to strategic and operational planning, provides basic information for achieving objectives, and serves as a control system[31].

PEMA has the same objective, namely, to help managers know the impacts of the company's activities and thus make internal strategic decisions. Unlike MEMA, however, it focuses primarily on impacts on the environment, expressed in physical units (tonnes of CO2 released into the atmosphere).

The PEMA used as an internal environmental accounting tool, performs several fundamental functions. Firstly, it serves to identify areas of strength and weakness in the environmental sphere, allowing accurate analysis of the organization's environmental

30 Roger L. Burritt et al. (2002), Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2, pages 2-3

31 Roger L. Burritt et al. (2002), Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2, pages 2-3

performance. Furthermore, it is used as a decision-support technique, focusing on relevant environmental aspects[32].

PEMA can be viewed through a lens that measures eco-efficiency, helping to assess the effectiveness of resource use about environmental impacts. Its functions include direct and indirect monitoring of the consequences of environmental impacts and providing useful data for mitigation or incremental action.

Finally, it acts as a tool for neutral and transparent communication with stakeholders, ensuring that the information shared is objective and reliable.

To obtain a clearer and more defined overall picture, three other very important dimensions must be added to the two dimensions PEMA and MEMA: the first is the time frame, which concerns the reference period of the instruments used for environmental accounting. The second is the length of the time frame, i.e. the duration of the period considered by the instrument.

The last is the routine of the information, which refers to the frequency with which the information is collected, distinguishing between those of a daily or otherwise frequent nature and those that are less recurrent[33].

Summarising then, the dimensions that make up the EMA framework are:

1. internal vs. external
2. monetary vs. physical classifications
3. past time frames vs future time frames
4. short term vs long term
5. ad hoc vs routine information.

The last very important factor to consider in developing an efficient EMA system is the quality of the information. This can be divided into two main categories.

32 Roger L. Burritt et al. (2002), Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2, pages 2-3
33 Roger L. Burritt et al. (2002), Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2, pages 4-5

The first is aggregated information, i.e. accounting data linked to long-term strategic decisions, used to plan and control activities at the company level, mainly by top management.

The second category includes specific information, which is timelier and more detailed than aggregated information. The latter is essential for operational managers, who use it to make short-term planning and control decisions[34].

Based on Porter's model, see figure below, it is possible to classify these types of information and understand to whom they are addressed:

34 Roger L. Burritt et al. (2002), Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2, pages 6

Figure 14: a Comprehensive EMA's framework

		Environmental Management Accounting (EMA)			
		Monetary Environmental Management Accounting (MEMA)		Physical Environmental Management Accounting (PEMA)	
		Short-Term	Long-Term	Short-Term	Long-Term
Past oriented	*Routinely generated information*	Environmental cost accounting (e.g. Variable costing, absorption costing, and activity-based costing	Environmentally induced capital expenditure and revenues	Material and energy flow accounting (short-term impacts on the environment – product, site, division, and company levels	Environmental capital impact accounting
	Ad Hoc information	Ex Post Assessment of relevant environmental costing decisions	Environmental life cycle (and target) costing Post-investment assessment of individual projects	Ex-post assessment of short-term environmental impacts	Life cycle inventories Post-investment assessment of physical environmental investment appraisal
Future oriented	*Routinely generated information*	Monetary environmental operational budgeting (Flows) Monetary environmental capital budgeting (stock)	Environmental long-term financial planning	Physical environmental budgeting (flows and stocks) (e.g. of a site product)	Long-term physical environmental planning
	Ad Hoc information	Relevant environmental costing (e.g. special orders, product mix with capacity constraints	Monetary environmental project investment appraisal Environmental life cycle budgeting and target pricing	Relevant environmental impacts	Physical environmental investment appraisal Life cycle analysis of specific projects

Elaboration based on: Roger L. Burritt, Tobias Hahn, Stefan Schaltegger, Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2

Based on Porter's model, see the following figures, it is possible to classify this type of information and understand who it is aimed at and the typologies of information[35]:

Figure 15: Value chain and internal corporate EMA users (based on Porter 1985)

Elaboration based on: Roger L. Burritt, Tobias Hahn, Stefan Schaltegger, Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2

35 Roger L. Burritt, Tobias Hahn, Stefan Schaltegger, Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2

Figure 16: Generic aims and objectives of different types of managers (Schaltegger et al 2001B)

GENERIC AIMS AND OBJECTIVES OF DIFFERENT TYPES OF MANAGERS (Schaltegger et al 2001B)		
Corporate EMA Systems		
Relevant EMA Users	**Basic goals**	**Type of information desired**
Top Management	• Long Term profitability and survival of the company • Securing legal compliance with minimal cost to the corporation • Realisation of all economically beneficial environmental protection measures • Securing the provision of resources from the critical stakeholders	Highly aggregated financial and strategic (qualitative and quantitative) information on the business environment and company's performance
Accounting and Finance Department	• Identifying and realizing cost-saving potential • Transparency about the environmental cost of activities on the income statement and/or balance sheet • Reduction of environmentally-induced-risks (Bennett and James) • Compliance with accounting regulations • Maximization of shareholder value	Financial measures about corporate activities, e.g., Cost, Income, balance sheet-related issues, risk assessments, investment decisions, mergers, acquisitions, etc.
Environmental Department	• Identifying environmental opportunities • Prioritizing environmental actions and measures • Environmental differentiation in product pricing, mix, and development decisions • Transparency about environmentally relevant corporate activities • Meeting the claims and information demands of critical environmental stakeholders, to ensure resource provision and access • Justifying environmental management division and environmental protection measures	Physical measures on material and energy flows and stocks and related processes and products, and their impacts upon the environment
Health and Safety Department	• Safeguarding the safety, health, and welfare of employees at work from environmental accidents, and disasters	Physical information on health and safety

Quality Department	• Meeting the (environmental) product requirements of customers at the minimum cost for a given level of product quality	Information on cost quality. Physical measures of technical product requirements
Human Resources Department	• Job-related (including environmental) concerns of employees • Remuneration, including rewards for good environmental performance • Physical jobs allocated and job conditions monitored	Information on financial rewards. Physical information on turnover, satisfaction, morale
Legal Department	• Ensuring (environmental) legal compliance by the company's operations	Physical measures. Qualitative compliance information
R&D and Design Department	• Development and design of marketable products and services • Reducing (environmental) risks of investments • Development of improved production processes	Strategic information about market demands. Financial information about costs of new products and services. Information on technical feasibility and environmental impacts of newly designed products and services.
Corporate Marketing and PR Department	• Meeting external information demands of critical stakeholders • Meeting claims and information demands of shareholders, and other economic stakeholders (including those interested in environmental reports) • Developing a green image of the company and its products	Information about stakeholder claims. Physical and financial information on the company's environmental impacts and efforts for pollution reduction and prevention
Production Management	• Task control over operations • Optimizing energy and material consumption • Reduction of environmentally induced risks	Information on quality and environmental proprieties of goods purchased.
Logistics	• Efficient organization of, collection, storage, and physical distribution of goods and products	Physical measures (e.g. on distribution means and storage facilities and related environmental impacts)

Marketing and Sales Department	• Increasing sales and attracting and satisfying buyers • Provision of means by which buyers can purchase the product • Including customers to buy the enterprise's product through the tools of the marketing mix	Information on operational market conditions (e.g. pricing, competitor activities, etc.) Information on customer demands
Disposal and Recycling Department	• Efficient disposal and recycling of wasted or used material • Minimization of wastes to be treated, especially hazardous wastes	Physical measures of the proprieties of disposable and recyclable goods. Technical information on treatment and recycling options

Elaboration based on: Roger L. Burritt, Tobias Hahn, Stefan Schaltegger, Towards a comprehensive framework for environmental management accounting – links between business actors and environmental management accounting tools, 2002, Australian accounting review Vol.12 No. 2

3.2. The MEMA and PEMA tools

MEMA mainly focuses, as mentioned above, on monitoring environmental costs in monetary terms and the financial benefits related to environmental management activities. One of the main monitoring tools is Environmental Cost Accounting (ECA). ECA can be seen as a flow-oriented system based on systematic cause/effect analysis and examines the entire environmental management system. The main objective is to identify inefficiencies in the chain and thus reduce the amount of environmental impacts and costs.

The process of applying ECA unfolds in five steps, the first being to identify environmental impacts, and in most cases, almost all impacts are caused by materials including storage, production, and distribution. It is necessary to classify these impacts according to their severity and only those with a high severity rate will be considered. The next step is to identify the cause of these impacts, which streams are affected by the environmental bills of materials, and in which activities they are used. A key step, then, is to assign a real monetary value to these flows; this value must come as close as possible to reality in order to avoid underestimating impacts and costs. Therefore, in this process, it is also necessary to include the costs related to logistics, management, and transport.

The last step is to assign environmental costs to a Cost Object, such as an input, a process, or a product[36].

Environmental Activity-Based Costing (EABC) is based on traditional accounting principles but with an environmental approach. The application process is identical to ABC (activity-based costing) and starts with the identification of consumption objects such as products, services, customers, or even markets. The identification of activity pools must be specific to the environmental activities obviously correlated with the cost structure they cause. Understanding what drives these costs, the cost drivers, and finally the most crucial step, the allocation of overhead costs to objects in the correct measure of activity and number of drivers.

The strength of this practice is that it allows the environmental costs caused by products and activities to be tracked through Cost Drivers[37].

Another widely used tool in waste management is Material Flow Cost Accounting (MFCA) to reduce waste, as it is one of the few tools for which international standards such as ISO 14501 - Environmental Management, developed in 2011, have been drawn up. This tool was developed in the late 1990s by the Institut für Management und Umwelt in Hamburg, Germany. Although it consists of both physical and monetary data, the MFCA is classified as a monetary EMA tool, relying on the monitoring of physical data, in particular material and energy flows, it is often past-oriented, focusing on the short term (it can also be used as a supplementary tool in environmental capital budgeting) and the information it uses is of a regular (routine) nature.

The first step in developing an MFCA is to establish the boundaries of the system, then it is necessary to monitor material and energy flows within the organisation, including using a flow diagram. However, attention must be paid to how and which flow diagrams are used as they are a heterogeneous representation of processes and as they are distinctive for each company, each model will be different from the other, and incorrect use could distort the entire process. Having done this, the next step is to assign a value (kg, tonnes, etc.) to the quantities handled in each phase within the flow diagram. The

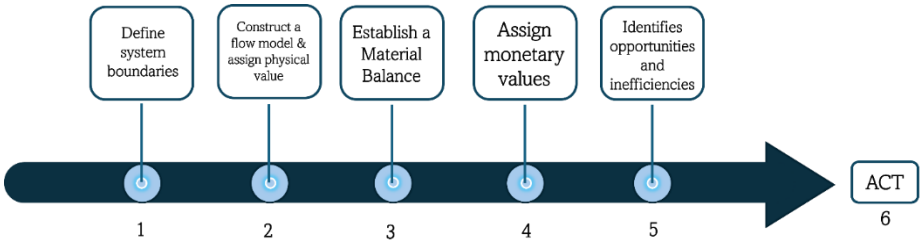
36 Peter Letmathe et al. (2000), Environmental cost accounting and auditing, Managerial Auditing Journal, Volume 15, articles 18, page 4
37 https://scindeks-clanci.ceon.rs/data/pdf/1450-7951/2021/1450-79512101053A.pdf

purpose of this step is to construct a material balance also called mass balance, input-output balance, or eco-balance.

After assigning a value to the flows, a monetary value must be assigned to them, which is why it is, MFCA, classified as a monetary EMA instrument.

The last two steps are to recognize, based on the data collected, opportunities and inefficiencies in the system and then act to reap the benefits or improve the inefficiencies[38].

Figure 17: The MFCA process



Elaboration based on: https://www.sciencedirect.com/science/article/pii/S0959652614009354#sec2

Turning to PEMA tools, which aim to monitor the impacts caused by a company's economic activities, unlike MEMA which uses monetary values, this method focuses more on physical measurements. There are several areas of PEMA monitoring, such as waste monitoring, electricity consumption, water consumption, and many others, but this thesis will mainly focus on the monitoring of greenhouse gases and their impacts.

To develop a valid Key Performance Indicator (KPI) that helps companies understand and monitor where emissions and related impacts are coming from, it needs to have certain characteristics.

A properly developed metric allows a company to understand the potential impacts of environmental and climate risks and the opportunities to be seized, including financial and operational impacts. It must have the fundamental characteristic of being clear and understandable as a metric becomes useful data can be evaluated on an aggregated and disaggregated basis, reflecting the strategies implemented to achieve, for example,

38 Katherine L. Christ et al (2015), Material flow cost accounting: a review and agenda for future research, 2015, Journal of Cleaner Production, Volume 108, part B, page 4

emission reduction targets and to understand inefficiencies in internal processes. Verifiability of data is an indispensable quality as this information can be used for external communication purposes, avoiding cognitive bias and personal judgments. Furthermore, it must be consistent over time, it must take into consideration a variable time horizon, from the past to the present to the future, to ensure comparisons and analysis of future trends.

In addition, metrics should be supported with a written description that helps users better understand the meaning and use of these metrics, with consistent information on financial and climate risks and opportunities[39].

Key climate change metrics, particularly physical monitoring of GHG emissions, must monitor 3 scopes of GHG emissions.

There are two methods for calculating emissions: the calculation of greenhouse gas emissions using Global Warming Potential (GWP), which is a standardized method for calculating emissions of various climate-altering gases in a standard unit of measurement, tonnes of CO2 equivalent. The advantage of this approach is that emissions with different global warming potential (GWP) values can be compared and summed up. This method consists of four steps.

The first step involves identifying the greenhouse gases emitted, including CO_2, CH_4, N_2O, and other gases such as HFCs, PFCs, and SF_6. Next, greenhouse gas emissions are measured: emissions must be quantified in terms of mass, usually expressed in kilograms or tonnes. These measurements can be carried out directly through measurement technologies or through the use of specific calculation models. The third step concerns the identification of Global Warming Potential[40] (GWP) values for each greenhouse gas produced. GWPs represent the amount of CO_2 emissions that would cause the same radiative forcing as a given amount of a well-mixed GHG, or a set of well-mixed GHGs, each multiplied by its global warming potential, in order to account for different

39 https://assets.bbhub.io/company/sites/60/2021/05/2021-TCFD-Metrics_Targets_Guidance.pdf
40 GWP represents the global warming effect of a gas over a 100-year period compared to CO_2.

residence times in the atmosphere. A table showing GWP values for various gases is presented below[41].

Figure 18: table on GWP values

Industrial designation or common name	Chemical formula	GWP values for 100-year time horizon		
		Second Assessment Report (SAR)	Fourth Assessment Report (AR4)	Fifth Assessment Report (AR5)
Carbon Dioxide	CO_2	1	1	1
Methane	CH_4	21	25	28
Nitrous Oxide	N_2O	310	298	265

Elaboration based on: https://ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

Finally, the mass of the gas has to be multiplied by its GWP: by applying the following formula, it is possible to know how much CO2 equivalent is released into the atmosphere.

$$CO2\ emissions = Gass\ Mass\ \times GWP$$

The second method of calculating greenhouse gas emissions is to use emission factors. Emission factors represent the average amount of greenhouse gases emitted per unit of activity, consumption, or energy production. These factors are standardized and can be consulted at national or international databases such as those of the IPCC, DEFRA[42], or ISPRA.

Once the corresponding emission factor has been found, to obtain the amount of greenhouse gas emissions, it must be multiplied by the amount of consumption or activity.

$$GHG\ emissions = Activity\ or\ Consume\ Quantity \times Emission\ Factors$$

41https://www.isprambiente.gov.it/it/attivita/cambiamenti-climatici/landamento-delle-emissioni/metodologie-di-stima

42 DEFRA: Department for Environment, Food and Rural Affairs. It is a department of the UK government responsible for the environment and agriculture.

Another way to quantify emissions along the entire value chain is the Life Cycle Assessment. It can be considered either a PEMA or a MEMA method, depending on how it is used[43].

The analysis of the Carbon Footprint through LCA is very complicated and time and resource-consuming for companies. This term, coined in the 1990s by two scholars called William E. Rees and Mathis Wackernagel, expresses a company's carbon footprint throughout its value chain in tonnes of CO2 equivalent per year.

Specifically, the LCA is an environmental management tool that measures a process, product, or service along the entire chain, from “Cradle to grave”. It can also be used as a decision support tool, an essential means of assessing the system and its impact in environmental terms[44].

The LCA consists of four essential steps: the first is the definition of the Goal and Scope. The second is the generation of an LCA Inventory (LCA Inventory Generation). The last two are Analysis and Assessment and Interpretation and discussion of the results.

There are various applications of the LCA model, such as the Attributional Life Cycle Assessment (ALCA) and the Consequential Life Cycle Assessment. The first refers to the analysis and monitoring of the direct impacts caused by the use of a product, process, or material. The second, the CLCA focuses on indirect impacts[45].

Focusing on the analysis of the Carbon Footprint through the LCA, the first phase Goal and Scope, is quite complex, as not correctly assessing or forgetting a particular aspect will compromise the entire reliability of the analysis and therefore must be conducted rigorously and carefully[46].

In this context, the Carbon Footprint analysis should serve to understand the dynamics of the entire life cycle of the processes, products, and services an organization offers that contribute to greenhouse gas emissions.

43 Subramanian Senthilkannan Muthu (2021), LCA Based CarbonFootprint Assessment, Springer, page 15
44 Subramanian Senthilkannan Muthu (2021), LCA Based CarbonFootprint Assessment, Springer, page 19
45 Subramanian Senthilkannan Muthu (2021), LCA Based CarbonFootprint Assessment, Springer, page 20
46 Subramanian Senthilkannan Muthu (2021), LCA Based CarbonFootprint Assessment, Springer, page 20

The emissions inventory phase can perhaps be considered the most important phase because it serves to delineate the boundaries and areas of interest related to emissions. Linked to this phase, the assessment of the impacts of an inventory allows activities to refer to their consequences. During the last phase, Interpretation and Recommendation, once the impacts have been identified, these impacts must be interpreted and quantified, and then possible remedies and recommendations identified[47].

Thus, in the end, LCA proves to be an indispensable tool not only for the quantification and analysis of greenhouse gas impacts but also for the definition of long-term strategies and the development of sustainability-oriented solutions. Thanks to its versatility, it can be used in many sectors, providing a solid basis for the development of virtuous practices that benefit the environment[48].

Another aspect that the EMA monitors is the environmental impact of investment portfolios concerning emissions through emissions-related financial metrics. These KPIs allow investors and individuals to understand the exposure of their portfolios to carbon emissions and to relate the environmental performance of assets in various sectors.

Among the most used metrics that have been developed over the years are the metrics relating to the weighted average carbon intensity, which measures the exposure of a portfolio in which there are stocks or shares with high carbon intensity, often such metric is expressed in terms of tCO2eq per million dollars of revenue. The Carbon Footprint, on the other hand, compares the total emissions of the portfolio to its market value, making it perfect for comparison with other portfolios. Another very important metric is carbon intensity which expresses carbon intensity, understood as the volume of emissions compared to revenues, useful for measuring one's environmental performance with a benchmark. The last metric that will be analyzed in this chapter is the Exposure to Carbon-based assets which measures the exposure of a portfolio to highly emission-intensive sectors, expressing the percentage or amount of carbon-related investments.

47 Subramanian Senthilkannan Muthu (2021), LCA Based CarbonFootprint Assessment, Springer, page 22
48 Subramanian Senthilkannan Muthu (2021), LCA Based CarbonFootprint Assessment, Springer, page 22

Let's see them in detail. The Weighted Average Carbon Intensity: This metric measures the portfolio's exposure to highly carbon-intensive companies, expressed in tCO2eq. /$M revenue.

$$\sum_{n}^{i}\left(\frac{Current\ value\ of\ investment}{Current\ value\ of\ portfolio}\times\frac{Issuer's\ Scope\ 1\ and\ Scope\ 2\ GHG\ emissions}{Issuer's\ \$M\ revenue}\right)$$

The strengths of this metric are that it is easy to understand and easy to apply to all asset classes as this metric does not rely on the share ownership approach[49].

The Total Carbon Emission: metric that expresses the absolute greenhouse gas emissions associated with the portfolio, expressed in tCO2eq.

$$\sum_{n}^{i}\left(\frac{Current\ value\ of\ investment}{Issuer'smarket\ capitalization}\times Issuer's\ Scope\ 1\ and\ Scope\ 2\ GHG\ emissions\right)$$

This metric can be used to communicate the carbon footprint of a portfolio in line with the GHG Protocol and to monitor changes in emissions in the portfolio. It is based on the equity ownership approach, that is, if an investor owns 5% of a company's market capitalization, then he owns 5% of the company's issues. Furthermore, it allows portfolio decomposition and attribution analysis. However, it cannot be used to compare portfolios as the data is not normalized[50].

If you want to compare with another portfolio or a benchmark, it is preferable to use the Carbon Footprint metric:

The Carbon Footprint: expresses the total emissions for a portfolio normalized by its market value, expressed in CO2eq/$M invested[51].

$$\frac{\sum_{n}^{i}\left(\frac{current\ value\ of\ investment}{Issuer's\ market\ capitalization}\times Issuer's\ Scope\ 1\ and\ 2\ GHG\ emissions\right)}{Current\ portfolio\ value\ (\$M)}$$

49 https://assets.bbhub.io/company/sites/60/2021/05/2021-TCFD-Metrics_Targets_Guidance.pdf
50 ttps://assets.bbhub.io/company/sites/60/2021/05/2021-TCFD-Metrics_Targets_Guidance.pdf
51 ttps://assets.bbhub.io/company/sites/60/2021/05/2021-TCFD-Metrics_Targets_Guidance.pdf

If a company wants to know the relationship between its emissions and its economic returns, it can use the Carbon Intensity, which expresses the volume of carbon emissions per million of revenues (portfolio carbon efficiency) expressed in tCO2/$M revenue.

$$\frac{\sum_n^i \left(\frac{Current\ value\ of\ investment}{Issuer's\ market\ capitalization} \times Issuer's\ Scope\ 1\ and\ Scope\ 2\ GHG\ emissions\right)}{\sum_n^i \left(\frac{Current\ value\ of\ investment}{Issuer's\ market\ capitalization} \times Issuer's\ \$M\ revenue\right)}$$

The company's (or Issuer's) revenues are used to adjust its size and measure the efficiency of the Outputs. This metric can also be used to compare different portfolios or with a benchmark. However, the calculation of this metric may be complicated and create some difficulties in communicating the results[52].

Exposure to Carbon-related Assets expresses the amount or percentage of carbon-related assets present in the portfolio. It is usually expressed in $M or a percentage of the portfolio value. So, there are two types of formulas:

1) Formula for the amount:

$$\sum \$M\ current\ value\ of\ investments\ in\ carbon\ related\ assets$$

2) Formula for percentage:

$$\frac{\sum Current\ value\ of\ investments\ in\ carbon\ related\ assets}{current\ portfolio\ value} \times 100$$

These two metrics focus on a portfolio's exposure to emissions-intensive sectors or industries[53].

In conclusion, these diversified and flexible metrics on the financial exposure of a portfolio to emissions help companies and investors to best manage the environmental impact of their investments. Which metric to use, however, depends on the objectives that these subjects aim to pursue and correct use will help them make better decisions and implement more efficient strategies from a sustainability point of view.

Briefly, a comprehensive and strategic approach for firms aims to manage greenhouse gas emissions and environmental impacts by using tools such as MEMA,

52 ttps://assets.bbhub.io/company/sites/60/2021/05/2021-TCFD-Metrics_Targets_Guidance.pdf
53 ttps://assets.bbhub.io/company/sites/60/2021/05/2021-TCFD-Metrics_Targets_Guidance.pdf

PEMA, and carbon-related financial measures. By implementing these methods, companies can disclose operational inefficiencies, accurately track environmental costs in terms of financial and physical resources and improve the sustainability of their operations. Companies can measure and manage their GHG emissions by integrating the GHG Protocol and other guidelines, such as the TCFD[54]. This also promotes greater transparency for investors and other stakeholders helping them to make more careful and responsible investment decisions by aligning financial objectives with environmental sustainability.

54 TFCD: Task Force on Climate-related Financial Disclosures (TCFD) is a body tasked with monitoring and promoting the stability of the global financial system, with the task of developing a series of recommendations on the reporting of risks related to climate change.

IV. Academic Literature Review

4.1. Introduction

The literature review is a fundamental phase in the writing of a degree thesis or academic research, as it allows you to explore and understand the state of the art of a particular topic, uncovering gaps and opportunities, and differences between the various schools of thought. This chapter will focus on a literature analysis, focused on the factors that drive companies to use carbon accounting, the main limitations, and an analysis of the various guidelines. Since it has now become a legal obligation to monitor and communicate their greenhouse gas emissions, understanding how it should be done is essential for companies that wish to comply with the CSRD directive to improve their business performance and also improve their image in the eyes of all stakeholders involved.

The GHG protocol represents one of the most widespread and recognized frameworks worldwide for the measurement and management of greenhouse gas inventories. Established to simplify and reduce the boundaries of measurement and reporting, supporting interested companies and entities. Therefore, the protocol provides detailed guidelines on the methodology to be used for measuring emissions, dividing them into Scope 1 (direct emissions), Scope 2 (indirect emissions from energy consumption), and finally, Scope 3 (other indirect emissions along the of value).

The use of these tools for the reporting and communication of greenhouse gas emissions allows companies to more stringently integrate financial and environmental aspects into corporate strategies and operations, increasing performance, reducing the associated risks, and responding to the growing environmental awareness of stakeholders.

However, there are still important challenges related to the complexity of data collection and management, measurement, and comparability between various international standards and guidelines. The objective of this analysis is to provide a common and critical vision of the main methodologies and requirements currently present, highlighting common practices and tools, gaps, and differences between them.

4.2. Literature search methodology

This literature search was conducted using keywords on the main databases available, such as Scopus, Google Scholar, and UnoPerTutto. To try to understand the state of the art of carbon accounting literature, the keywords used were: “Carbon Accounting”; “ESG and Carbon Accounting”; “Sustainability”; “GHG Protocol”; AI and Carbon Accounting; “GRI”; Carbon Reporting”; “Carbon Accounting”; and “Financial performance” and “LCA”.

The objective of this research is therefore to understand what the main trends are of thought regarding carbon accounting, the factors that push companies to use carbon accounting, the main benefits and limitations and future scenarios and what is the relationship between a company's financial performance and greenhouse gas emissions.

4.3. Results

4.3.1. The Growing Importance of Carbon Accounting

Rapid development and modernization have made the natural environment increasingly vulnerable and lacking in resources, creating the need to find a solution or at least mitigate its effects. These problems are also reflected in the economic world, making it necessary to start detecting the impacts of one's actions with well-defined metrics, even by companies. Accounting has proven to be very useful in managing climate change thanks to the changes it has brought to the way companies estimate risks, prepare reports, and organize long-term strategies. Climate change, greenhouse gas emissions, and other human-induced issues create physical, transient, and regulatory risks that impact business operations[55].

Carbon accounting could become a fundamental approach by which companies support business decisions regarding climate change mitigation and in reporting environmental outcomes. They highlight that this is a field of research aimed at improving the transparency and robustness of the carbon accounting system. The measurement of

55 N. Abhishek et al. (2024), Carbon management accounting an evolving approach to enhance transparency and accountability in accounting and reporting practices, Journal of Accounting & Organizational Change, page 1

greenhouse gases (GHG) are essential aspect of aligning companies with global sustainability objectives.[56]

Companies need tools based on rigorous parameters to integrate carbon data into decision-making, management, and disclosure processes, in order to improve the credibility and comparability of the information disclosed.

Being an emerging accounting paradigm that quantifies the carbon emissions produced by economic activities, based on the hypothesis that a management approach, such as "carbon cost management", helps to internalize the environmental costs deriving from business operations, demonstrating that this approach can influence in-depth managerial accounting models and sustainability reporting standards, outlining new environmental performance metrics and improving climate risk management[57].

The use of carbon accounting in business practices allows organizations to have tools to address risks and opportunities, encouraging innovation, reducing costs and mitigating the impacts of their economic and non-economic actions. Thanks to carbon accounting, companies can analyze themselves internally from a critical point of view to determine the potential financial implications of risks related to climate change and make more informed decisions regarding the allocation of both physical and financial resources[58].

4.3.2. Benefits and Challenges of Implementing Carbon Accounting

Looking at the economic side, the implementation of a carbon accounting system involves extraordinary costs that must be taken into consideration: just think of the expenses for software, hardware, human capital, and training, which are not within the reach of all companies. Implementing these mechanisms for small and medium-sized companies could be complicated and very expensive. The positive side of the coin to consider is the possible reduction in costs and emissions, and greater efficiency if an

56 Jillene Marlowe et al. (2021), Carbon Accounting: A Systematic Literature Review and Directions for Future Research, AimsPress - Green Finance, Volume 4, article 1, page 9
57 Muh. Ardiansyah Syam1 et al. (2024), Carbon Accounting: Its Implications on Accounting Practices and Corporate Sustainability Reports, 2024, International Journal of Economics and Financial Issues, Volume 14, article 4, page 2
58 N. Abhishek et al. (2024), Carbon management accounting an evolving approach to enhance transparency and accountability in accounting and reporting practices, Journal of Accounting & Organizational Change, page 8

adequate and well-structured control system is established. Furthermore, a well-designed control system allows companies to join carbon trading scheme programs, attributing a precise monetary value to their emissions, and creating incentives for a possible reduction of them[59].

From a brand image and visibility point of view, a good system can help companies improve their reputation, showing their dedication to mitigating their impacts and increasing social responsibility, it can increase the company's attractiveness for new climate-conscious investors and customers, human capital, as well as access to credit[60].

Another very important factor to consider in addition to measuring environmental impacts is the audit and benchmarking system: comparisons between standards and guidelines and environmental performance are essential to ensure compliance and achieve climate goals. The eco-audit is based on systematic and regular monitoring procedures on the environmental impacts of companies, and these procedures allow an effective comparison between internal numbers and objectives or standards, but also an evaluation of progress, helping companies to increase business efficiency[61].

Carbon accounting, therefore, not only provides a functional framework for measuring and reporting GHG emissions but also constitutes the fundamental pillar for the implementation of emission reduction strategies in line with international commitments, such as the SDGs. In particular, it supports the evaluation of the financial implications of investments in sustainability projects and supports companies in achieving their emissions reduction objectives. This approach allows companies to monitor, but also effectively reduce emissions through the adoption of low-emission technologies and improved energy efficiency[62].

59 N. Abhishek et al. (2024), Carbon management accounting an evolving approach to enhance transparency and accountability in accounting and reporting practices, Journal of Accounting & Organizational Change, page 21

60 N. Abhishek et al. (2024), Carbon management accounting an evolving approach to enhance transparency and accountability in accounting and reporting practices, Journal of Accounting & Organizational Change, page 21

61 Wei Qian et al. (2018), Environmental management accounting and its effects on carbon management and disclosure quality, Journal of Cleaner Production, Volume 174, pp. 1608-1619

62 N. Abhishek et al. (2024), Carbon management accounting an evolving approach to enhance transparency and accountability in accounting and reporting practices, Journal of Accounting & Organizational Change, page 21

However, one of the most critical aspects of carbon accounting is the variability of the metrics and guidelines used: just think, for example, of how companies monitor the intensity of emissions, some relating them to economic budget components such as revenues or EBITDA, other physical units such as the number of products sold, or in the case of energy companies, emissions are often compared with the quantity of barrels produced or KWh, or, companies in the transport sector often compare emissions with the kilometers traveled. Several studies show that, although existing standards such as the GHG Protocol have been put in place, measurement methodologies and systems are highly variable, making it difficult to compare environmental performance between companies. This inconsistency represents a major problem for investors and stakeholders who need reliable and comparable information to make informed decisions[63].

The lack of global standardization and homogeneity in carbon accounting practices leads to the emergence of significant discrepancies in sustainability reports and difficulties in comparability between companies. This variability arises partly from the absence of binding international standards and partly from the freedom of choice in methods of measuring emissions. This variability, for example, is particularly evident in the measurement of Scope 3 emissions, for which the GHG Protocol guidelines offer only a general framework, leaving ample room for maneuver and variability in company practices[64].

Monitoring indirect emissions across the entire business value chain, particularly those classified as "Scope 3 emissions" arises indirectly from suppliers and customers through their activities. While Scope 1 and 2 emissions, respectively direct emissions, and indirect emissions related to energy consumption, can be monitored and quantified with some reliability, Scope 3 emissions represent a challenge complex for carbon accounting, as they require companies to analyze and report the impact of third parties[65].

This complexity highlights the need to develop closer relationships with suppliers and implement responsible sourcing practices to reduce emissions across the lifecycle of

63 Jillene Marlowe et al. (2021), Carbon Accounting: A Systematic Literature Review and Directions for Future Research, AimsPress - Green Finance, Volume 4, article 1, page 11
64 Rong Hea et al. (2020), Corporate carbon accounting: a literature review of carbon accounting research from the Kyoto Protocol to the Paris Agreement, Accounting & Finance, page 18
65 Rong Hea et al. (2020), Corporate carbon accounting: a literature review of carbon accounting research from the Kyoto Protocol to the Paris Agreement, Accounting & Finance, page 18-19

products. The guidelines offered by the regulations express only a draft of how scope 3 emissions should be calculated, often leaving companies with carte blanche. However, the difficulty in finding such information often forces companies to carry out an often incomplete calculation, as some items are often unquantifiable or require an enormous effort in terms of time and work. Therefore, the availability and correctness of information represent one of the main challenges that must be resolved for correct accounting of emissions.

Measuring indirect emissions along the entire value chain is the most complicated task of measuring scope 3 emissions as all indirect emissions deriving from assets not directly controlled or owned by the organization but which occur within the organization must be monitored along its value chain. Scope 3 emissions involve parties that are interconnected with each other, from suppliers to customers and consumers, creating problems in reporting the emissions of all parties involved.

This area requires a rigorous and complete method that affects the entire chain, consequently due to its complexity, various tools have been developed, such as the Life cycle assessment, and standards and guidelines have been drawn up to ensure that they are monitored and reported correctly[66].

Various approaches have been developed for life cycle assessment: one of these is the input-output model based on standard top-down techniques that can be applied to different types of services and products. On the contrary, process-based LCA models adopt a bottom-up approach that estimates the impact of emissions on each phase of a product's life cycle.

However, this approach is quite expensive in terms of time and resources and is based on the definition of organizational boundaries which, considering the entire value chain, can cause incorrect accounting of emissions as parts of the chain may not be taken into consideration[67].

66 Elisa Truant, Edoardo Crocco et al. (2023), Life cycle thinking and carbon accounting in sustainable supply chains: a structured literature review and research agenda, Sustainability Accounting, Management and Policy Journal, page 15

67 Elisa Truant, Edoardo Crocco et al. (2023), Life cycle thinking and carbon accounting in sustainable supply chains: a structured literature review and research agenda, Sustainability Accounting, Management and Policy Journal, page 15

4.3.3. Tools and Frameworks for Carbon Accounting

On this topic, the academic literature has established 3 main strands on why to adopt LCA: the first concerns the thinking behind LCA, driven by external pressures, which is based on a cultural approach which is life cycle thinking, as it allows companies to respond to pressure from stakeholders who are increasingly attentive to environmental aspects.

The second strand argues that LCA is one of the most suitable tools for conducting rigorous and accurate analyzes of all emissions along the entire value chain. Proof of this is that this lifecycle thinking approach is increasingly manifested in sustainability reports. However, scholars point out that such thinking focuses more on the carbon footprint of products and services, not the entire organization[68].

In addition to these two lines, the literature says that it can positively influence the decision-making process of an investment, therefore it can be seen as a bridge between the network of international regulations and the market which is increasingly attentive to environmental issues[69].

In any case, attention must be paid to the fact that this tool is influenced by the product sector in which it is used and therefore its peculiarity can drastically influence the implementation of a correct lifecycle. Therefore, the main problem of LCA is its problematic standardization: the use of innovative approaches such as blockchain, artificial intelligence, and advanced sensor systems, such as smart meters, have the potential to improve this approach, optimizing transparency, traceability, and efficiency. A final essential element of LCA, which should be further analyzed by the literature, is the circular economy, as it allows emissions to be reduced by adopting the circularity of products and materials[70].

68 Elisa Truant, Edoardo Crocco et al. (2023), Life cycle thinking and carbon accounting in sustainable supply chains: a structured literature review and research agenda, Sustainability Accounting, Management and Policy Journal, page 15-16
69 Elisa Truant, Edoardo Crocco et al. (2023), Life cycle thinking and carbon accounting in sustainable supply chains: a structured literature review and research agenda, Sustainability Accounting, Management and Policy Journal, page 15-16
70 Elisa Truant, Edoardo Crocco et al. (2023), Life cycle thinking and carbon accounting in sustainable supply chains: a structured literature review and research agenda, Sustainability Accounting, Management and Policy Journal, page 15-16

Thus, companies have ample room for maneuvering on the methodologies, companies can use different ones to calculate the 3 scopes, such as the calculation through the emission factor the GWP, or the Life Cycle Assessment.

Another aspect to consider is how companies monitor their emissions, for example using the GHG Protocol or other guidelines. The most followed is the GHG Protocol, born in 1999 from a multi-stakeholder partnership made up of companies, non-governmental organizations (NGOs), governments, and other entities, established by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The WRI is a US-based environmental NGO, while the WBCSD is a Geneva-based coalition of 170 international companies.

The partnership's work produced two related documents:

1) GHG Protocol Corporate Accounting and Reporting Standard: guides companies step-by-step in quantifying and reporting GHG emissions.
2) GHG Protocol Project Quantification Standard: Still in development, provides guidance for quantifying reductions from greenhouse gas mitigation projects.

The main purpose of the GHG Protocol is to provide standardized information on greenhouse gas emissions both for internal management processes and for external reporting reasons based on reliable and verified data.

This approach suggested by the GHG Protocol is based on the consolidation method, which determines the organizational boundaries of the company, according to an Equity Share approach or control approach. The first refers to the emissions that are associated with the share of equity that a company owns in an investment, however, the control method consists of allocating 100% of the emissions caused by the operations or activities that the company controls.

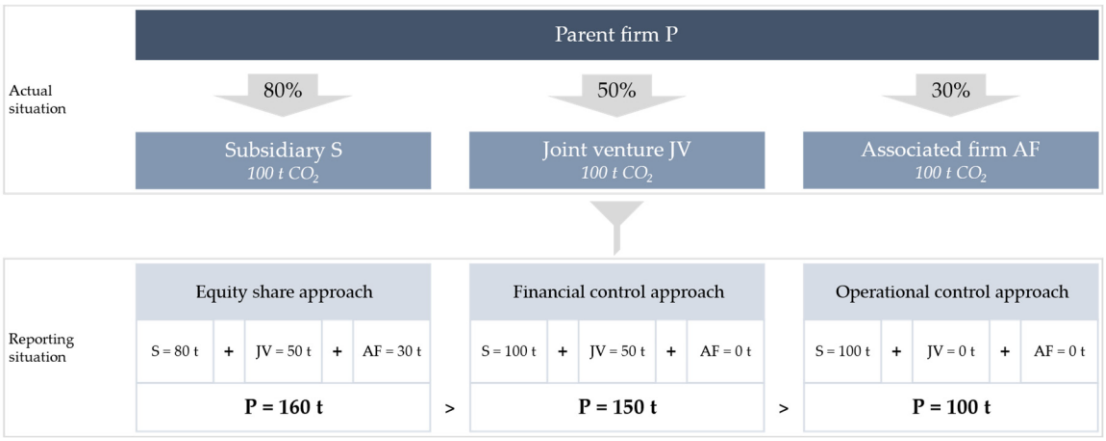
Therefore, it does not account for issues resulting from transactions in which it owns an equity interest but does not have control over it. This control can be expressed in financial or operational terms: Financial control occurs when a company has financial control over an operation and has the ability to influence and direct its financial and operational policies, with the aim of obtaining economic benefits. For example, if Company If this criterion is selected, the emissions caused by Joint Ventures in which the

parties have joint financial control are to be reported following the shareholding approach[71].

Operational control, on the other hand, occurs when a company has operational control over an activity or operation if it or one of its controlled companies has full authority to influence and implement the operational policies and strategies of the operation[72].

In summary, companies can choose three types of approaches: equity share, financial control, and operational control. The following figure, by way of example, shows how the use of these different approaches leads to different reporting of emissions[73].

Figure 18: the three types of approaches to control



Source: Rainer Kasperzak et al (2023), Accounting for Carbon Emissions - Current State of Sustainability Reporting Practice under the GHG Protocol, MDPI Sustainability, Volume 15, Article 2

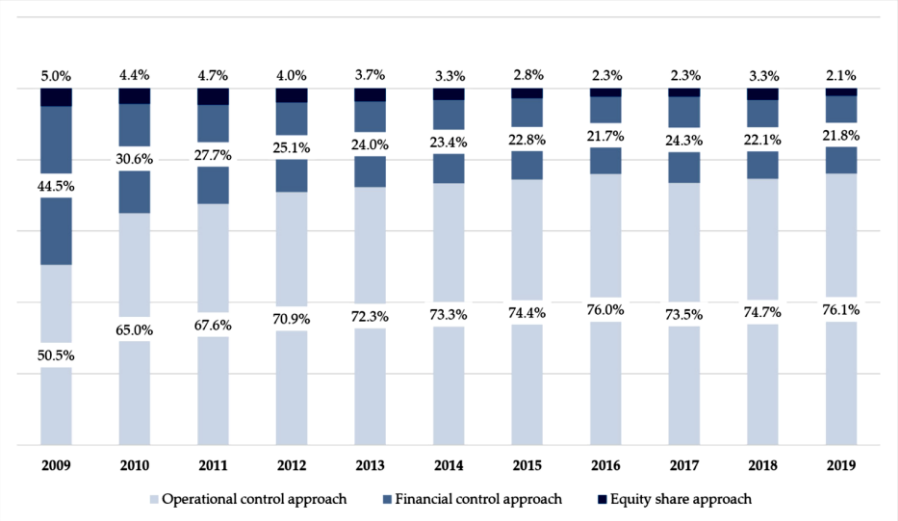
However, criticism has been raised about how the choice of a different approach leads to a different reporting of emissions. As can be seen from the figure, the control approach leads to a lower reporting of declared emissions, while financial control leads to a larger quantity as the emissions held as a percentage in a joint venture or similar

71 Rainer Kasperzak et al (2023), Accounting for Carbon Emissions - Current State of Sustainability Reporting Practice under the GHG Protocol, MDPI Sustainability, Volume 15, article 2, page 4
72 Rainer Kasperzak et al (2023), Accounting for Carbon Emissions - Current State of Sustainability Reporting Practice under the GHG Protocol, MDPI Sustainability, Volume 15, article 2, page 4
73 Rainer Kasperzak et al (2023), Accounting for Carbon Emissions - Current State of Sustainability Reporting Practice under the GHG Protocol, MDPI Sustainability, Volume 15, article 2, page 4

agreements are also declared by the parent company. If the company has many subsidiaries or joint ventures, this approach leads to higher emissions being declared compared to other approaches. The opposite case occurs when a company has many subsidiaries in which it holds only a small majority share and few associates or joint ventures[74].

In the academic article Accounting for Carbon Emissions - Current State of Sustainability Reporting Practice under the GHG Protocol by Kasperzak, Rainer, Kureljusic Marko, Reisch Lucas, and Thies Simon, the evolution of the distribution of each approach over time is also analyzed. The empirical results denoted a clear predominance of the control method for reporting emissions compared to the other two approaches[75].

Figure 19: time evolution of the type of control



Source: Rainer Kasperzak et al (2023), Accounting for Carbon Emissions - Current State of Sustainability Reporting Practice under the GHG Protocol, MDPI Sustainability, Volume 15, Article 2

The results resulting from their analysis show how the share of the control method has increased by approximately 50% in the last eleven years covered by their sample, becoming the most used method[76].

74 Rainer Kasperzak et al (2023), Accounting for Carbon Emissions - Current State of Sustainability Reporting Practice under the GHG Protocol, MDPI Sustainability, Volume 15, article 2, page 7
75 Rainer Kasperzak et al (2023), Accounting for Carbon Emissions - Current State of Sustainability Reporting Practice under the GHG Protocol, MDPI Sustainability, Volume 15, article 2, page 7
76 Rainer Kasperzak et al (2023), Accounting for Carbon Emissions - Current State of Sustainability Reporting Practice under the GHG Protocol, MDPI Sustainability, Volume 15, article 2, page 7

Added to all this is the variability of the data and its quality. One of the main problems of carbon accounting is finding a reliable monitoring system that guarantees their availability, transparency, and quality. Often such data is manipulated to clean the image, just think of the Volkswagen case of 2015, in which the well-known Group was accused of having falsified the emissions emitted by their Diesel engines.

The last aspect to consider is how greenhouse gas emissions relate to financial performance. The article Corporate Carbon and Financial Performance: The Role of Emission Reductions by S. Lewandowsky analyzes this relationship. In particular, it examines how annual reported greenhouse gas measurements influence a company's financial components and reduction improvements. According to the IPCC report, emissions projections are expected to increase over time and efforts to mitigate this increase by companies have not yet fully manifested themselves. The results of his analysis provide evidence of a curvilinear association between emissions and financial performance, showing a generally positive link for companies with high emissions and a negative one for those with lower performance.

So, it may be advantageous for companies to engage in emissions mitigation programs only after exceeding a certain greenhouse gas threshold. This relationship takes the shape of a "U", which implies that the type of association depends more on a company's emissions level and that they benefit if their emissions performance is comparatively high, highlighting the fact that companies with low financial performance face trade-offs between pollution reduction and competitiveness[77].

As regards emission reduction programs, the empirical results proposed by this research do not provide any evidence of the curvilinear relationship between emission reductions and financial performance. Another interesting fact that is highlighted in this research is that the association between improvements in emissions and stock market performance is linear and negative, indicating that companies suffer limitations if they implement improvement programs.

This relationship indicates that companies have little incentive to reduce their emissions beyond a certain threshold that allows for a positive association between them

77 Stefan Lewandowski (2017), Corporate Carbon and Financial Performance: The Role of Emission Reductions, Wiley online library, Volume 26, issue 8, page 10

and that companies are therefore ineffective, despite growing regulatory pressure, in dealing with change climate. in short, those who pollute more can benefit more from reductions in terms of financial performance but for those who pollute less this relationship does not manifest itself[78].

A solution to this problem can be provided by emission permits, as companies can capitalize on their reductions, through the trading quota system established by the European Union, taking economic advantage from emissions compensation projects. However, several criticisms have been raised regarding this instrument as emissions reduction and compensation projects, such as tree planting, lead to a reduction or compensation of emissions in different places where they take place, in addition to this specific In this case, it takes several years before a tree can absorb CO2.

4.3.4. Future Directions and Standardization Efforts

At the moment there are already several efforts to align such discrepancies such as EFRAG, or the European Financial Reporting Advisory Group.

Therefore, EFRAG's activities are articulated in 2 pillars: the first, the financial reporting pillar influences the development of IFRS accounting standards according to the European perspective and how they contribute to the efficiency of the markets. The second pillar is Sustainability Reporting, that is, the development of the ESRS drafts to comply with the principles of the CSRD directive and future amendments for the European Commission. Since the interoperability of its principles is one of its main objectives, EFRAG has become a member of the IFRS Sustainability Standards Advisory Forum (SSAF) and collaborates with regional and international groups for the development of sustainability reporting, as with the staff of ISSB, on a regular basis.

Furthermore, in 2023, EFRAG and the GRI, another international body responsible for drafting sustainability standards, jointly published a joint statement on the high degree of interoperability achieved by the ESRS and GRI standards.

The growth in the choice of Global Reporting Initiative (GRI) guidelines for emissions reporting has been supported over the last two decades by collaboration

78 Stefan Lewandowski (2017), Corporate Carbon and Financial Performance: The Role of Emission Reductions, Wiley online library, Volume 26, issue 8, page 10

between the United Nations to promote the Sustainable Development Goals (SDGs) and sustainability reporting. Furthermore, it is necessary to underline the involvement of Stakeholders in the GRI principles. Studies conducted have highlighted how the GRI guidelines can improve the quality of the data and information provided[79].

The GRI Standards, or Global Reporting Initiative, represent today one of the most widespread and appreciated global frameworks for sustainability reporting. These standards offer organizations a structured model that allows them to disclose their economic, environmental, and social impacts transparently and comparably. As a benchmark, GRI standards enable businesses, governments, and other institutions to independently measure and report their sustainability performance, thereby helping to identify and manage risks and opportunities, as well as promote social responsibility and improved practices. corporate.

The GRI standards framework is based on three main pillars: the GRI 1 Foundation, which establishes the fundamental principles for reporting. The GRI 2 General Disclosures, relate to general information on governance, structures, and operational practices, and finally, the GRI 3 Material Topics, which helps the organization in selecting the material topics to report.

In addition to these 3 documents that can be applied to reporting, the GRI has also developed industry standards and thematic standards. These thematic standards cover various topics, including energy, greenhouse gas emissions, and others.

Today, in fact, the GRI is probably one of the main tools in the world for sustainability reporting, adopted by numerous companies globally. Companies that choose GRI standards also document their contribution to achieving the United Nations Sustainable Development Goals by actively supporting responsible and sustainable practices. This framework was designed to be modular and flexible, thus leaving organizations the freedom to select the most relevant standards for their specific sector and context.

79 Muhammad Nurul Houqe et al (2022), What determines the quality of carbon reporting? A system-oriented theories and corporate governance perspective, Wiley online library, volume 32, issue 6, page 6

A final example of these efforts is the Science-Based Targets Initiative (SBTi), which provides a global framework for companies to set emissions reduction targets aligned with the latest scientific developments on climate change. The SBTi is a collaboration between the Carbon Disclosure Project (CDP), the World Resources Institute (WRI), the Worldwide Fund for Nature (WWF), and the United Nations Global Compact (UNGC) and seeks to align corporate strategies with the goals of the Paris Agreement, that is, to limit global warming to well below 2°C, to reach 1.5°C above pre-industrial levels.

Technology can be of great help: thanks to emissions management software based on artificial intelligence, companies can address many of the challenges associated with carbon accounting. Automated data collection for reporting helps generate better assessments of emissions-related impacts, risks, and opportunities.

Thanks to such software it is possible to produce metrics that can be supported by data that are verifiable at every stage of the process. Furthermore, by having access to an internal source of shared and reliable information, all the stakeholders involved, and staff can make correct decisions to achieve their objectives[80].

By using predictive emissions analytics to assess variances between predicted and actual outcomes, carbon accountants can identify significant variations that they can review and investigate possible errors[81].

However, it must be considered that the use of software based on artificial intelligence partially solves the problem as it does not lower the costs of carbon accounting, ongoing innovations, and regulatory changes. Its role is to increase the accuracy, speed, and efficiency of data collection. Furthermore, it should be considered that in any case, AI models require accurate and correct data sets to guarantee their

80 Abdulrahman Saad H. Alqahtani (2023), Application of Artificial Intelligence in Carbon Accounting and Firm Performance: A Review Using Qualitative Analysis, International Journal of experimental research and review, page 7
81 Abdulrahman Saad H. Alqahtani (2023), Application of Artificial Intelligence in Carbon Accounting and Firm Performance: A Review Using Qualitative Analysis, International Journal of experimental research and review, page 7

efficiency and one of the main problems that AI cannot answer is the availability and accessibility of data, as it is up to companies to solve this task[82].

4.4. Conclusions

In conclusion, this literature review has highlighted how carbon accounting can be used as a key tool to respond to environmental challenges related to greenhouse gas emissions. Best practices and reporting standards such as the GHG Protocol, SBTi, and the GRI demonstrate how they are essential to help companies monitor their impacts, aligning with global targets and increasing corporate environmental performance.

However, some significant gaps have emerged, the variability of data and guidelines, and the difficulties in measuring scope 3 emissions, represent a challenge to be resolved for correct and comparable reporting.

The analysis highlighted how the LCA (life cycle assessment) is one of the most versatile tools, capable of evaluating the life cycle of emissions of the entire value chain, both used according to a PEMA tool perspective and as a monetary instrument (MEMA).

In any case, given its complexity and high costs they are limiting its adoption, especially for small and medium-sized businesses. Even with the use of advanced technologies such as AI and Blockchain, which promise to promote transparency and efficiency, the problem is not completely resolved, problems relating to the availability of data and the costs and resources needed remain.

Furthermore, it emerges that the potential of carbon accounting in helping companies make business decisions and strategies, reduce their impacts, and improve corporate reputation both internally and externally has not yet been fully exploited.

Finally, a positive connection between emissions reductions and a company's financial performance was highlighted, however, this topic requires further investigation. This criticism raised by some scholars suggests that only companies with high emissions

82 Abdulrahman Saad H. Alqahtani (2023), Application of Artificial Intelligence in Carbon Accounting and Firm Performance: A Review Using Qualitative Analysis, International Journal of experimental research and review, page 7-8

derive clear benefits from their reduction programs, while other, smaller companies may encounter considerable difficulties in implementing them.

This review provided an analysis of the methodologies and challenges of carbon accounting, highlighting the need for greater harmonization of practices and greater collaboration between stakeholders, companies, and institutions.

Chapter V. Empirical analysis

5.1. Introduction

In recent years, increasing environmental awareness and attention, the exponential growth of extreme weather events and climate change have forced companies to respond to these environmental issues by taking concrete actions to reduce their carbon footprint and thus combat climate change. Now, reporting and monitoring sustainability and greenhouse gas emissions have become indispensable elements in monitoring companies' environmental impacts, establishing mitigation strategies, and showing transparency to all stakeholders.

Increasing regulatory pressure, such as the emergence of the European Green Deal, and new reporting regulations such as the Corporate Social Responsibility Directive (CSRD) and the European Sustainability Reporting Standards (ESRS) have further pushed companies to adhere to sustainable practices and global standards such as the Global Reporting Initiative (GRI), the Task Force on Climate-related Financial Disclosures or the Science-Based Target Initiative (SBTi).

The monitoring of greenhouse gas emissions is a very complex and complicated practice, requiring the correct identification of emission sources, so-called Scopes, the use of standardized calculation methodologies, and the use of key performance indicators (KPIs) to report and communicate progress toward sustainable goals. Furthermore, it is increasingly evident how emissions management can influence a company's financial performance, raising questions about the role of sustainability as a competitive lever.

The objective of this analysis is to analyze the emissions and their reporting of a sample of 60 companies operating in different markets, paying close attention to

compliance with European directives and global standards, e.g. assessing the adoption of GRI, TCFD, or SBTi standards and their impact on the quality of reports. Furthermore, given the wide variability of the standards in circulation found in the literature review, this analysis has as a secondary objective to monitor this variability and thus those most followed.

Another key point on which it is based is the methodology for calculating emissions: thus, the three scopes are monitored and calculated, focusing on the three main practices, such as calculation using emission factors or GWP and lifecycle assessment.

The next step is the analysis of the specific KPIs suggested by the various international standards, such as emission intensity, reductions, and internal carbon pricing.

In the literature analysis, a relationship was also found between emissions and the financial performance of a company, thus, what kind of correlation there is between these two variables.

With this analysis, it aims to answer the following research questions:

- To what extent do companies exhibit variability in the application of sustainability reporting standards, and how does this affect the comparability of their reports?
- Does the analyzed pool of companies exhibit variability in the application of sustainability standards, and how do they plan to ensure compliance with international and regulatory requirements?
- Which sustainability standards are the most widely used by companies and how do they ensure compliance with these frameworks?
- What are the main methodologies for calculating the KPIs on GHG emissions and with what degree of transparency?
- What are the main gaps in sustainability reports, and how they could be filled?

In addition, a descriptive analysis of GHG emissions and the financial performance of companies, in particular EBITDA, was conducted, and thus whether there is a degree of correlation between them and future trends. Finally, the test analysis proposed an index of companies' alignment of sustainability reporting with current regulations and standards.

5.2. The dataset

5.2.1. Criteria for selecting companies

The dataset taken into consideration consists of data on GHG emissions, employees, and EBITDA of a sample of 60 companies belonging to different sectors. In particular, sectors were taken into consideration according to which there was evidence of high emission intensity and, therefore, companies from the energy, manufacturing, industrial, technology, and large-scale retail trade (GDO) sectors.

The companies belonging to the different sectors were selected based on their inclusion in indices and ETFs[83] in which companies with high performance in ESG reporting and monitoring were included.

Thus, companies were selected from the iShares Dow Jones Eurozone Sustainability Screened UCITS ETF (DE), the MIB ESG, and finally the iShares MSCI Europe Climate Transition Aware UCITS ETF.

The first, the iShares Dow Jones Eurozone Sustainability Screened UCITS ETF (DE), is an index fund that invests in Eurozone companies selected based on sustainability criteria. This ETF excludes companies involved in controversial sectors (such as arms, tobacco, and coal) or that do not meet certain environmental, social, and governance (ESG) standards.

The objective of this index is to provide exposure to European companies that comply with sustainability criteria while leaving out those that are deemed to have unaccountable practices, in particular, companies that are found to have controversial human and labor rights issues, companies that are involved in the nuclear and coal industries and those that are involved in the arms and tobacco trade.

This index aims to replicate, under passive management, the performance of the Dow Jones Eurozone Sustainability Screened Index. Within this analysis, the companies included in this ETF can be seen as those that seek to balance financial performance and sustainability.

83 ETF (Exchange-Traded Fund): it is a marketable security that tracks an index, sector, commodity, or asset class

This ETF is composed of companies belonging to different sectors, in particular, 25.22% of the companies examined are from the technology sector, 20.67% from the financial sector, 14.15% from the industrial sector, and finally 8.64% from the manufacturing sector. The main companies included by holdings are: ASML Holding, Sap SE, Siemens AG, Totalenergies SE, and finally Schneider Electric SE. As for the ETF's geographical allocation, it is concentrated in France with 32.06% of the total holdings, Germany with 22.03%, the Netherlands with 16.76%, and Spain with 16.11%.

The second criterion for choosing companies was based on companies belonging to the MIB ESG index. This index of Borsa Italiana integrates environmental, social, and governance (ESG) criteria in the selection of companies listed on the Italian stock market. The creation of this index was done to promote sustainable investments, giving sustainable performance-conscious investors a benchmark consisting of companies that declare and comply with strict sustainability requirements, while pursuing solid economic and financial performance.

To be included in this index, companies are evaluated by the FTSE MIB according to strict criteria, including greenhouse gas emission management, energy efficiency, and sustainable resource management practices.

For social aspects, the criteria considered are inclusion, diversity, workers' rights, and community impact. Finally, for governance aspects, transparent management practices are monitored.

As with the iShares Dow Jones Eurozone Sustainability Screened UCITS ETF (DE), companies belonging to controversial sectors, such as those related to the arms trade, coal, and tobacco, have been excluded a priori. Thus, its composition is made up of leading Italian companies in terms of sustainability, and among the main ones are Enel, Intesa Sanpaolo, Snam, and Hera.

The main sectors that make up this index are energy, public and environmental services, banking, industry, manufacturing, and finally technology.

The last selection criterion concerns companies belonging to the iShares MSCI Europe Climate Transition Aware UCITS ETF. This ETF aims to replicate the performance of the Index focusing on European companies that are in line with the

transition to a low-carbon economy, having been established to bring companies in line with global climate targets.

The methodology for inclusion in this index is done using ESG criteria to select companies with a low climate risk profile and, like the others, excludes companies that are part of controversial markets.

In terms of its current composition, it is diversified across several sectors, including technology, finance, energy, manufacturing, and services, and its geographic distribution is composed of French, German, and British companies, from the Netherlands, and other European states.

The distribution of analysis companies by both country and sector is shown below:

Figure 20: Distribution of companies per country

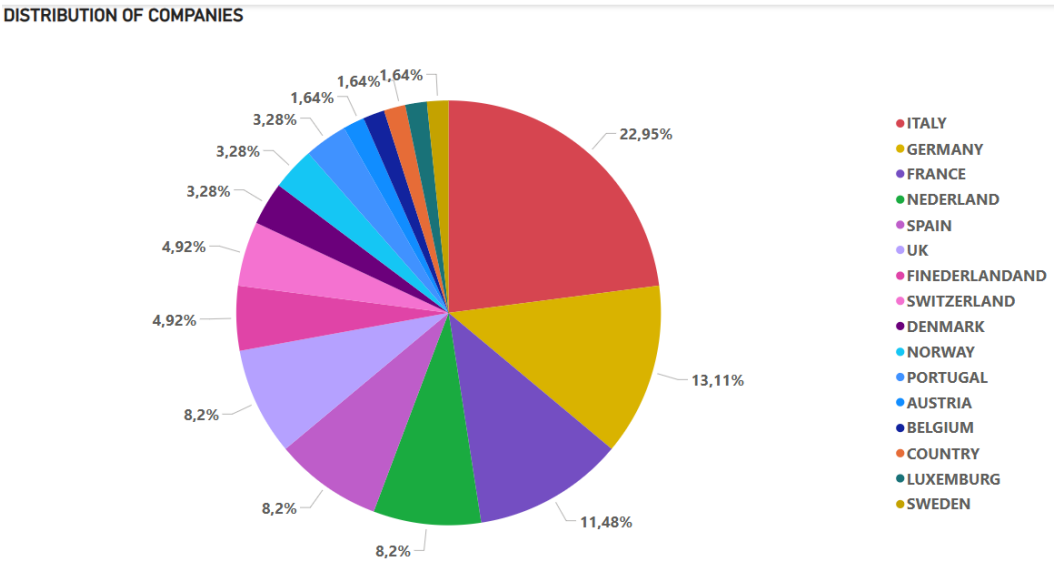
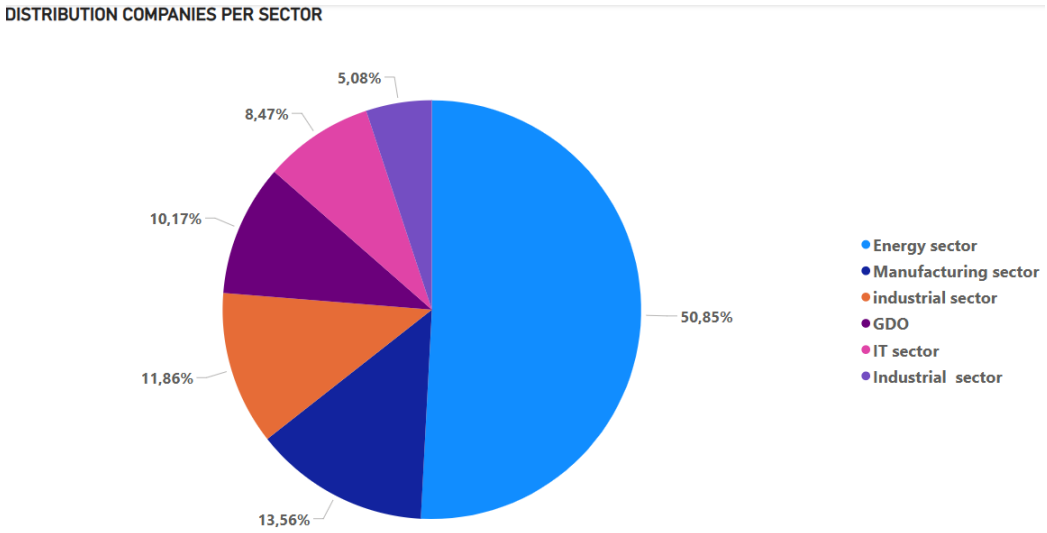


Figure 21: Distribution of companies per sector



5.2.2. Type of data

Three main types of data were used to conduct this analysis:

- numerical data: the time horizon considered for these data is the period 2021-2023.
  - Scope 1, 2 (Location-Based and Market-Based) and 3 GHG emissions (in MtCO2eq.)
  - EBITDA
  - number of employees
  - The intensity of emissions
- Categorical data: this data were taken from the sustainability reports 2023 of the companies on their websites.
  - The guidelines used for the preparation of sustainability reports, specifically those of the GRI (Global Reporting Initiative), TFCD (Task Force Climate Change Disclosure), SASB[84] (Sustainability Accounting Standard Board), and SDGs.

84 SASB (Sustainability Accounting Standards Board): it is an independent nonprofit organization that develops standards to guide the disclosure of financially material sustainability information by companies to their investor

- the emission factor used (IPCC, DEFRA, CDP, GHG Protocol, UNFCCC, and others).
- The calculation methodology, whether it was done through the emission factor, GWP, or through lifecycle assessment.
- The primary KPIs for emission reporting, as recommended by the guidelines, include Scope 1, Scope 2, and Scope 3 emissions, carbon intensity, carbon footprint, achieved emission reductions, and avoided emissions.
- The methodologies for calculating these KPIs should adhere to established guidelines, including the GHG Protocol, the Science-Based Targets Initiative (SBTi) for setting scientifically grounded reduction targets, the Task Force on Climate-related Financial Disclosures (TCFD), and relevant ISO standards.
- This includes assessing the presence and type of Internal Carbon Pricing, such as shadow pricing, and internal carbon fees.
- Whether reduction targets are pursued for 2030 and 2050.
- Whether an external auditor audited their sustainability report, and if so who.

5.2.3. Collection data Methodology

For the type of data, numerical data, in particular those related to EBITDA and the number of employees, were collected through the international ORBIS database, while the 3 Scope and emission intensity through the 2023 Sustainability Reports, were taken from the relevant websites.

Concerning categorical data, such as the guidelines used, the emission factor used, the main KPIs monitored, the methodology used to calculate emissions, the guidelines followed for their calculation, the presence and type of internal carbon pricing, the reduction targets and finally the presence or absence of an external auditor, were collected, again, through a manual examination of the sustainability reports of each company examined, in particular in the methodological note section, Environmental, appendices and connection tables.

About the missing data, specifically for the EBITDA data 2021-2023, the reference data of four companies in the dataset are missing, for the data on employees, the missing data are two. Finally, for the categorical data, no useful information was found for three companies in the population for all categories considered.

5.2.4. The descriptive analysis of numerical data

The analysis described is a key step in understanding the structure and main characteristics of the dataset. It provides a general overview of the data, which enables an understanding of the data distribution and significant trends.

The main objective of this analysis is to identify the trend of emissions in particular its evolution with the introduction of the CSRD, the market sectors that have identified the highest emissions and thus, those that have reduced their emissions the most, and finally, the emissions broken down by the reference index or ETF.

Subsequently, the analysis will mainly focus on the classic variables examined during a descriptive statistics analysis, both for the EBITDA variable and for GHG emissions, such as the mean, and median to describe the central values, the minimum and maximum points and percentiles to understand the distribution and variability of the data, and finally the standard deviation to assess the dispersion.

Finally, the results will be represented using graphs and tables that will allow the information found to be identified and communicated clearly and effectively.

5.2.5. The descriptive analysis of categorical variables

As mentioned earlier, the collection of information on categorical data was done by dissecting each 2023 sustainability report of each company in the sample and once the information was identified, it was directly reported in the overall database using two binary variables. Zero, ‘0’, if the required information was not present and, one, ‘1’, if it was present.

The purpose of this method is to identify the variability of the most widely used standards and guidelines present, the main guidelines for calculating emissions, and thus the most commonly used methodologies, the main ones that must be reported to be as compliant as possible with the guidelines. Furthermore, whether companies have set emission reduction targets and finally, whether the data and information provided have been effectively verified by third parties.

In addition, an index of company alignment to the main guidelines was constructed using the results of this research.

This index is based on the set of binary variables (1= present, 0 = not present) indicating whether the company meets these specific criteria. It should be noted, however, that with regard to these categories, the presence of more than one 1 (1=present), does not give the company a higher score, but simply in the selected category, there must be at least one '1' present for the requirement to be fulfilled.

Once the necessary calculations had been made, the scores obtained for each category were added together to obtain a final raw score. This raw score was then divided by the total attainable score and multiplied by one hundred to obtain a percentage estimate.

$$Alignment\ Index = \left(\frac{Obtained\ Score}{Total\ Score}\right) x\ 100$$

The descriptive analysis will provide a detailed overview of the main characteristics of the dataset, highlighting significant patterns, variations between companies, and potential gaps in emissions reporting and sustainability practices. The construction of the alignment index will summarize the companies' level of compliance with ESG criteria and international standards. However, it should be noted that this index is purely crude and does not consider possible different weights given to the categories and other variables to be considered, as academic and educational sources were not found on this issue.

These preliminary results lay the groundwork for more specific insights, such as the analysis of correlations between emission trends and economic performance and allow for the identification of critical areas in need of improvement by companies.

In the next section, the results of the analysis and the resulting implications will be presented, with a focus on the alignment of companies to sustainability targets and the relationships between the analyzed data.

5.3. The results

This section is dedicated to the results of the in-depth analysis of the information collected and emerging from the data, to answer those questions that emerged from the literature

review and assess the degree to which companies are aligned with the main guidelines on emissions reporting and monitoring.

Furthermore, the results that emerged will make it possible to analyze patterns and significant variations in emissions also with EBITDA and thus, understand whether there is indeed a relationship between financial performance and emissions.

5.3.1 The results of the distribution

Thus, starting from the analysis of the emissions trend for the three years 2021-2023, through the representation of the data, as can be seen in the graph, the emissions trend suggests a downward trend. Specifically, in 2021 the total sum of emissions stood at 6100k tons CO2eq, while in 2023 they decreased to 5750k total emissions.

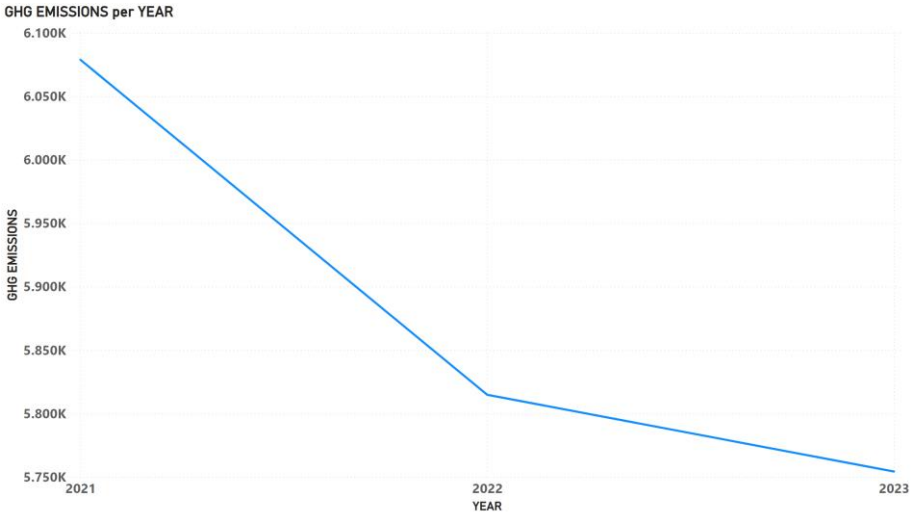
The trend suggests that annually the reduction is constant, highlighting how companies have undertaken reduction plans or implemented decarbonization and energy efficiency policies. It should also be noted that the introduction of the CSRD law at the turn of 2022-2023 also had a contribution to reducing emissions. Specifically, the rate of emission reduction, using 2021 values as a base year, is - 4.34% for 2021-2022 and -1.04% for 2022-2023.

Table 1: GHG emission reduction rate

YEAR	REDUCTION RATE
2021	0%
2022	- 4,34%
2023	-1,04%

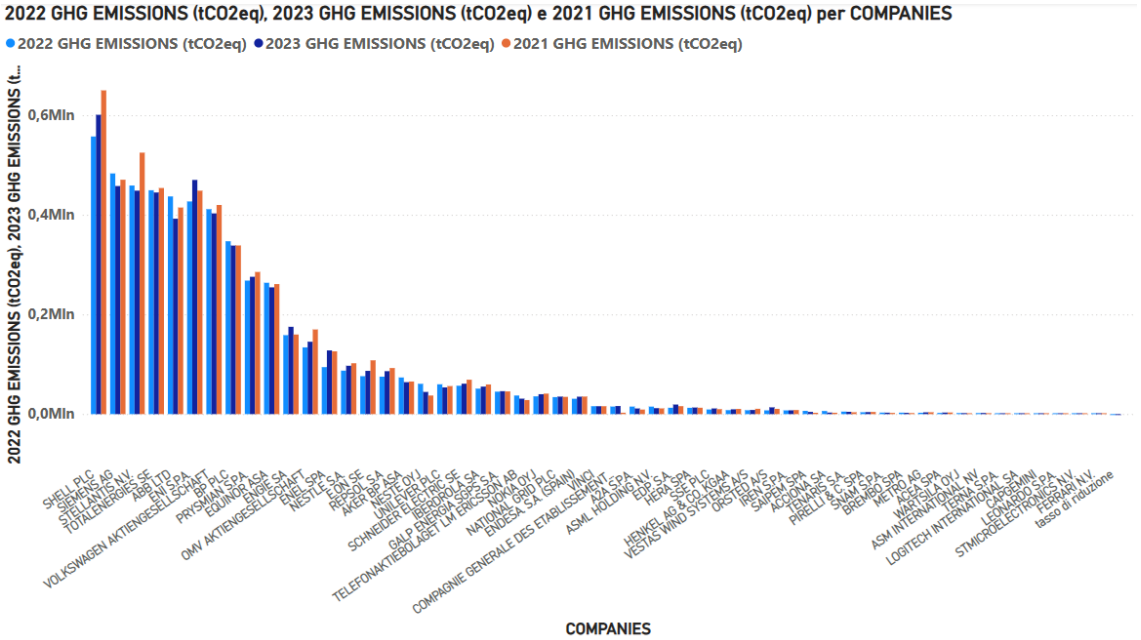
So overall, the data collected show significant progress towards reducing the carbon footprint, however, it must be considered that the time series examined is not sufficiently robust to allow a more accurate analysis of current and future trends.

Figure 22: the trend 2021-2023 of GHG emissions



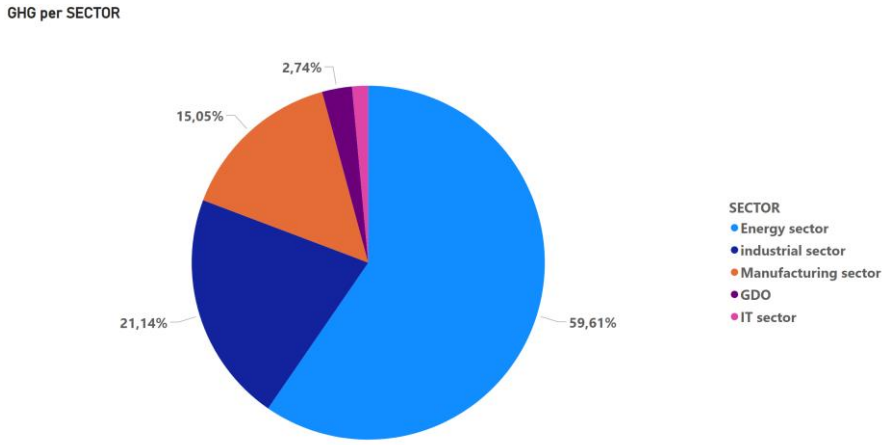
Furthermore, the following graph, represents the trend in emissions, again for the same three-year period, broken down by the sixty companies surveyed, highlighting how there is a commitment to reduce emissions. As can be seen from the graph, the vast majority of companies have undertaken reduction and efficiency plans, although there are cases in which these reductions have not manifested themselves and have even increased over time.

Figure 23: GHG emissions per company



Analyzing the emissions by sector, as we can see from the pie chart, as was to be expected, the Energy Sector is the sector most responsible for greenhouse gas emissions, followed by the Industrial Sector, the Manufacturing Sector, and finally the Retail and IT Sector. This dominance of the energy sector can be justified by two facts: the first, that the main activities of these companies include fossil sources such as oil, gas, or coal, for energy generation, underlining the need to prioritize the decarbonization of this sector, and from such reduction plans, the other sectors could also benefit. The second is because Shell plc is present in the sample, which is the company with by far the largest emissions figure compared to all the others.

Figure 24: GHG emissions per sector

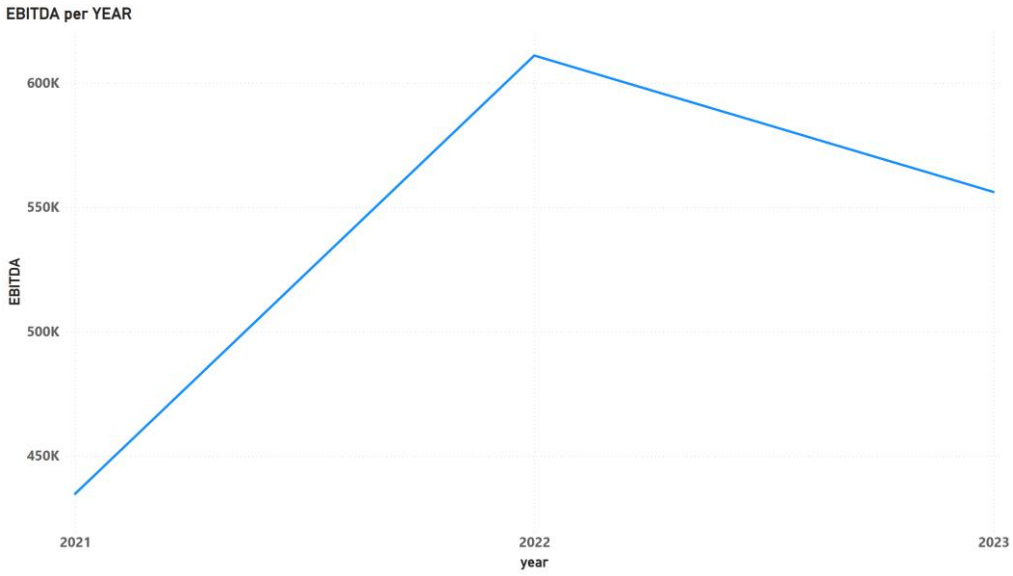


Analyzing the issues by index or reference ETF, we can also see that the iShares Dow Jones Eurozone Sustainability Screened UCITS ETF (DE), is the main source of issues in relation to the MIB ESG and the iShares MSCI Europe Climate Transition Aware UCITS ETF.

The reduction in total emissions over the same three-year period and the decrease in total EBITDA observed from 2022 onwards could indicate a possible alignment with the hypothesis that companies are undertaking activities or investments to reduce emissions. It is important to note that changes in EBITDA alone cannot directly confirm such investments. This is because EBITDA is influenced by several factors, including

operating performance, market dynamics, and general economic conditions. To support this assumption, further analysis of capital expenditures or data on the company's sustainability initiatives would be required.

Figure 25: the trend 2021-2023 of the EBITDA



However, it must be emphasized that this is an assumption based primarily on these data, and an in-depth analysis of the consolidated financial statements of the companies should be conducted to verify these investments.

To confirm this statement, even though it should be further investigated by introducing other variables, a correlation index between emissions and EBITDA was prepared. The value of 0.75 indicates a strong positive correlation, partially supporting the hypothesis that a reduction in emissions leads to a reduction in EBITDA. However, this statement should be taken with a grain of salt as the influence of other determined variables such as the Capex of the companies should be verified.

Table 2: correlation index EBITDA - GHG emissions

Total correlation index (EBITDA – GHG emissions)	0,7523

5.3.2. The results of the descriptive statistics analysis of numerical data

Moving on to the analysis of the descriptive statistics for both emissions and EBITDA, the following results were analyzed: the minimum and maximum points, the median, the mean, the percentiles, and the standard deviation.

Table 3: descriptive analysis of GHG emissions

DESCRIPTIVE STATS GHG EMISSIONS (tCO2eq.)	2021	2022	2023
MIN	101	98	34,50
MAX	1.079.000	969.000	936.000
MEDIAN	12.095,60	19.200	23.355
MEAN	105.034,29	109.713,51	99.075,70
0,25 PERCENTILE	2.755,25	4.050	6.284,85
0,50 PERCENTILE	12.095,60	19.200	23.355
0,75 PERCENTILE	103.595	97.060	75.920
STANDARD DEVIATION	200.225,47	187.098,76	178.791,21

By analyzing the minimum and maximum points we can see how these maximums and minimums reduce over time, indicating a reduction in emissions, theoretically confirming the implementation of emission reduction plans. The decrease in the total annual average of emissions, which culminated in 2023, places a further element in the hypothesis that these reductions resulted from sustainable investments. However, it must be underlined that the comparison between the median and the mean suggests that the extreme values (particularly the maximum) significantly influence the mean.

For the percentiles, in particular, for the 25th percentile, a constant increase in this value is observed, leading to the assumption that companies with the lowest emissions have recorded a growth in their environmental impact. The hypothesis behind this statement lies in the fact that companies have seen an expansion of their activities and therefore of emissions or a proven difficulty in implementing reduction plans. However, it should be noted that companies in the 75th percentile, i.e. companies with high emissions, have seen a reduction in these emissions, suggesting that they may be subject to more stringent rules (such as emissions permits) or have implemented plans for reduction efficiently, investing in more energy efficient technologies and processes. This

large gap between the 25th and 75th percentiles highlights how, perhaps, smaller companies need greater incentives or more stringent obligations to align with the general trend.

The analysis of the standard deviation of emissions, which represents a measure of dispersion, which indicates how much the emission values differ on average from the arithmetic mean, for the three years 2021-2023, indicates that there is a clear decline in the standard deviation, showing how the emissions are progressively alienating with the arithmetic mean, suggesting that they are becoming more homogeneous. This increase in homogeneity could be caused by the introduction of more stringent regulations which have had a greater impact on large emitters, which raise the maximum values, compared to companies with lower emissions, with a consequent reduction in the maximum values and therefore in the variability.

Moving the analysis of the statistic described to EBITDA, the minimum values show a significant improvement, going from a negative value in 2021 to a positive one in 2023, showing how companies with lower financial performances are improving their position. On the contrary, the high points drop markedly, highlighting that these companies have experienced more pronounced economic fluctuations, perhaps due in part to investments, including reduction programs, which have not yet generated considerable profits, affecting the overall economic result.

Table 4: descriptive analysis of EBITDA

DESCRIPTIVE STATS EBITDA (million €)	**2021**	**2022**	**2023**
MIN	- 7.245 €	- 508 €	525,70 €
MAX	47.361,81 €	80.264,43 €	59.504,05 €
MEDIAN	3.555,81 €	3.574,37 €	4.166,21 €
MEAN	7.762,08 €	10.911,13 €	9.931,17 €
0,25 PERCENTILE	1.250,35 €	1.337,80 €	1.706,47 €
0,50 PERCENTILE	3.555,81 €	3.574,37 €	4.166,20 €
0,75 PERCENTILE	8.428,25 €	11.395,61 €	11.610,5 €
STANDARD DEVIATION	11.297,10 €	17.939,38 €	13.117,47 €

The proof of this is provided by the percentiles: looking at the trend of the 25th percentile, the low-end companies are improving their position while the companies belonging to the 75th are recording a slowdown in terms of profits.

The standard deviation increased dramatically in 2022, going from a value of 11297.10 to a value of 17939.39, suggesting a wide dispersion in the results. However, in 2023 it is reduced, showing a convergence of results, with less variability among companies, resulting from a post-pandemic adjustment or more favorable market conditions.

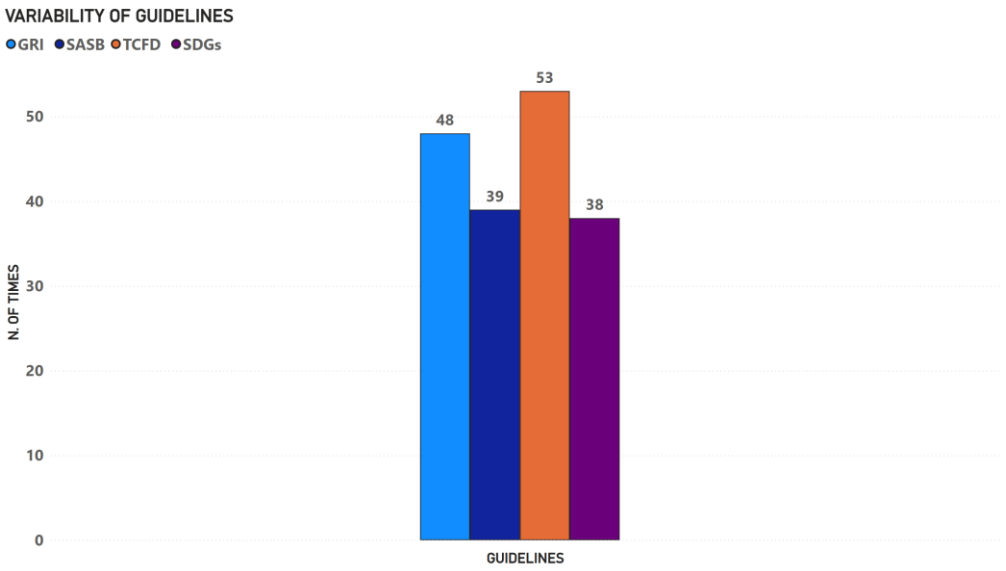
5.3.3. The results of the analysis of categorical data

The analysis of the results of the categorical data turns out to be a fundamental step to understanding how companies are aligning themselves with European guidelines and standards. These data extrapolated from the sustainability reports of the companies examined, include relevant information on the guidelines followed and their variability in use, the emission factors used, the reporting of the main KPIs suggested by the guidelines, how emissions are calculated, and which guidelines were followed for their calculation, the reduction objectives set and finally the verification of the information by an external auditor. Furthermore, an analysis of the results of the company alignment index will be proposed.

Starting from the guidelines, those examined are the main ones in Europe: the GRI, TCFD, SASB, and finally the SDGs guidelines. the SDGs are not actual guidelines, but targets, specifically seventeen, that the United Nations have developed to lead countries towards a more sustainable approach. These targets have been widely recognized throughout Europe, so much so that they have become an indispensable element of sustainability reporting.

The results (see graph) show how there is a certain variability in the adoption of the various guidelines used.

Figure 26: variability of Guidelines

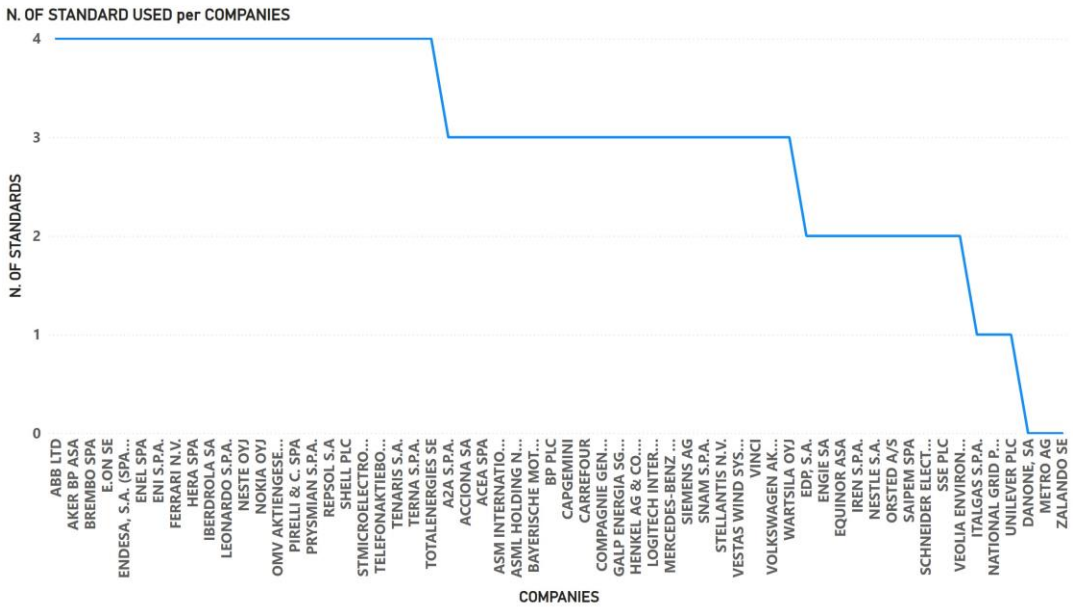


As we can see from the graph, the most used guideline is that of the TCFD, reflecting the growing importance of information related to climate risks and the regulatory push of the CSRD which always requires transparency on strategies related to climate change.

In second position is the GRI, being one of the most renowned and long-standing guidelines in circulation, it is a solid and adequate source on how to draw up sustainability reports. It must be underlined that in the future if there is no adaptation to the dual materiality approach proposed by the CSRD, the use of this guide may suffer a decline. In the last position, we find the SDGs guidelines, underlining how companies are still trying to understand how to align with the 17 sustainable development goals.

It must be underlined that many companies have relied on multiple guidelines to draw up their sustainability reports and therefore this is not a negative point, but simply indicates that there is no single way to draw up these financial statements.

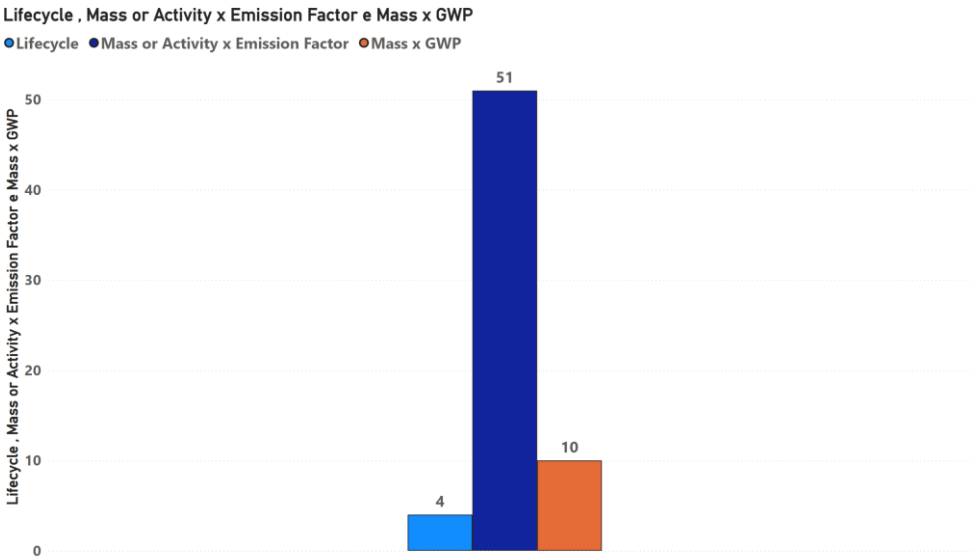
Figure 27: number of standards used per company



The resulting data shows how the majority of companies have used multiple guidelines to report on sustainable issues. A crucial point to focus on is that the lack of a single guideline to use can cause difficult comparisons of data between different companies and sectors, due to the different reporting criteria. In light of this, however, with the introduction of ESRS, the European Union aims to fill this gap.

As regards the results of the main emissions calculation methodology, as we can see from the graph, the mass * emission factor method comes in first place.

Figure 28: GHG emission methodology



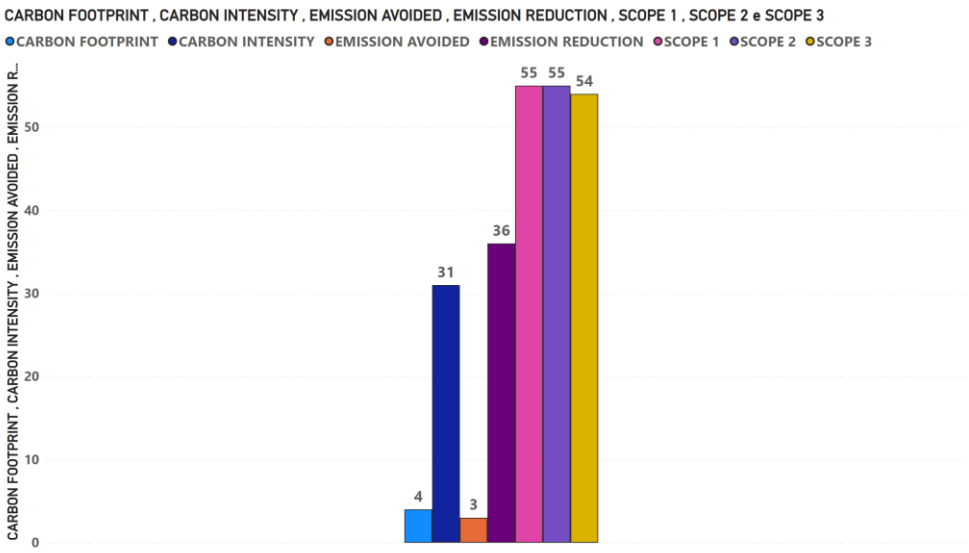
With a value of 51, this methodology was used by 51 companies out of the total sample.

Also, in this case, some companies have used different calculation methodologies, for example, to count gas emissions, in particular refrigerant gases, it is preferable to use the GWP compared to the classic emission factor, as the GWP offers greater precision in the conversion of emissions of specific refrigerant gases. In the last position, we find the lifecycle Assessment: its little use is certainly justified by the prohibitive costs of implementation and resources and its complexity, and this result is also confirmed by the analysis of the literature in the previous chapter.

The main KPIs that were suggested by the guidelines are those relating to the emissions of the three scopes, the intensity of emissions, emission reductions, the carbon footprint, and emissions avoided.

As can be seen from the graph, companies have not had major problems in reporting their emissions according to the three scopes. With a count of approximately 55 times out of 60 companies, these three KPIs are the ones that companies have reported the most.

Figure 29: KPI monitored



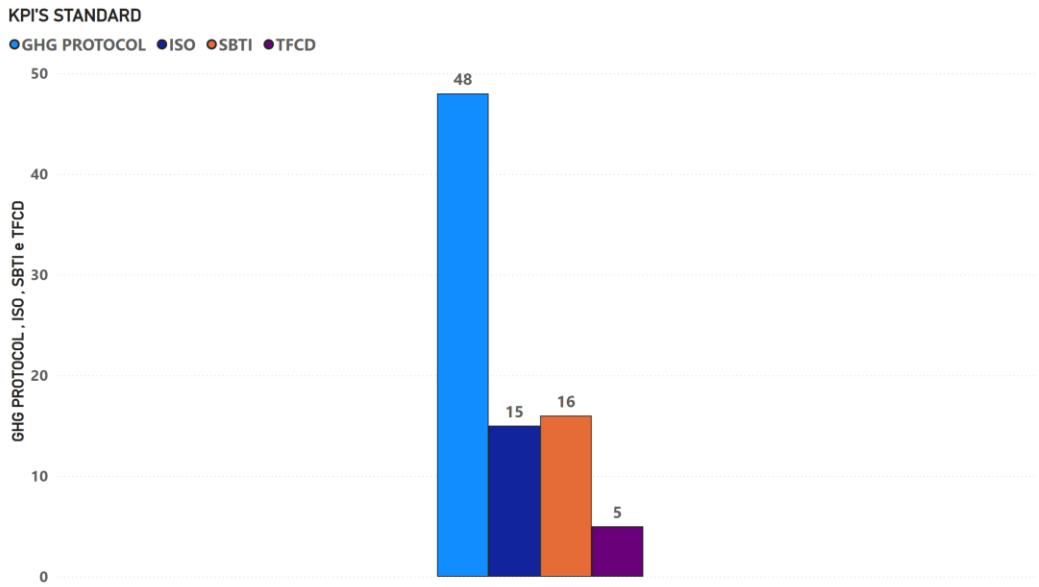
As regards the KPIs relating to reductions and carbon intensity, 36 and 31 companies respectively monitored them out of a total of 60. In the last two positions, we find avoided emissions and carbon footprint: their extremely low monitoring could have been caused both by the difficulty of physically reporting avoided emissions and by the

difficulty of implementing a system that monitors the entire carbon footprint of the value chain, including suppliers.

Confirmation of this can be found in the trend on which guidelines to use for KPI monitoring. The GHG Protocol, in first position with 48 points, focuses more on the reporting and monitoring of scope 1, 2, and 3 emissions, while for example, the low use of the SBTi, focuses more on emissions reductions, highlighting just as the reduction KPI in the previous table was monitored by only half of the companies in the sample.

Again, it must be underlined that even in this case, companies have used multiple guidelines to monitor more specific KPIs to have a more accurate measurement.

Figure 30: KPI's standards



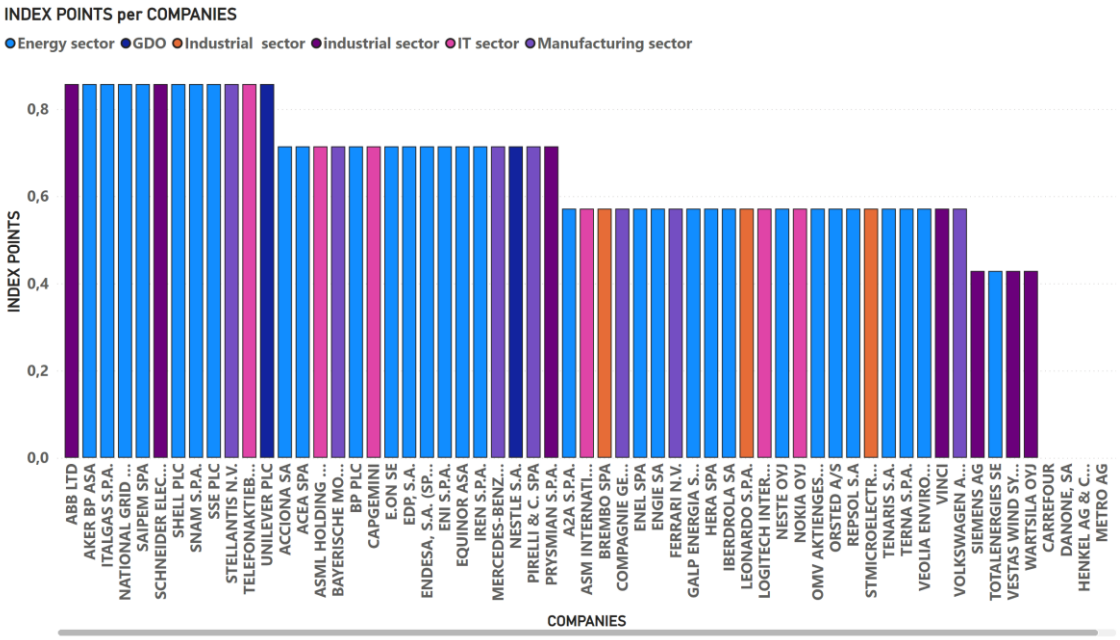
The results on the use of internal carbon pricing did not produce satisfactory results for drawing conclusions on which type of internal carbon pricing companies use. Since in most of the reports analyzed its use is not mentioned, and if it had been done, it is not specified which type of internal carbon price was used.

The final analysis regarding the categorical data is done in the presence or absence of an external auditor to verify the truthfulness of the information communicated. With the release of the CSRD directive, obliged companies must have their information verified by a third party to guarantee the transparency and correctness of the data.

The results obtained say that 45 out of 60 companies have verified their information through external auditors, suggesting that companies are in line with this practice.

To combine all this information collected and evaluate the degree of alignment of companies with the proposed guidelines, a rough alignment index was developed, the construction of which was explained in the previous paragraphs.

Figure 32: index points per company

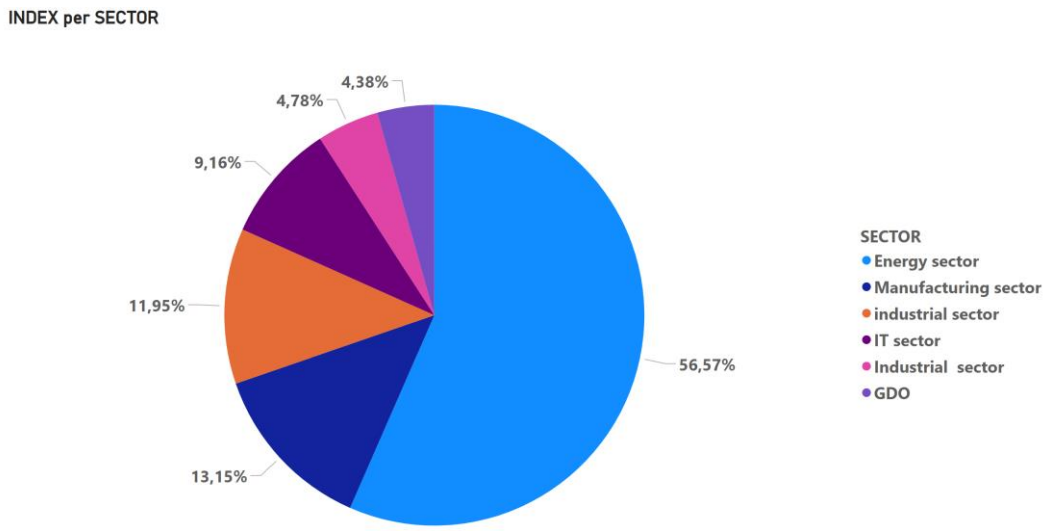


The results of this index show how there is a certain degree of alignment of companies with the guidelines, specifically highlighting how companies with the highest scores belong to the industrial and energy sector, assuming that they have suffered the most from the obligation to adopt the reporting and monitoring principles indicated by the CSRD directive.

In the 0.6 – 0.8 range, most companies did not fully comply with the requirements suggested by the guidelines, such as the KPI on emissions reductions and external auditor verification. Finally, as regards companies with a score lower than 0.6, can be considered behind in compliance with the guidelines but this lack could be justified by the fact that not all of them have the means to be immediately aligned with the required requirements or to sectoral and structural difficulties.

Analyzing the distribution of values obtained by companies for the sector to which they belong, as can be seen from the graph, the dominant sector of this index is the Energy Sector, settling at a value of 56.57%, followed by the Manufacturing Sector, the Industrial Sector and finally the last two, the IT Sector and the GDO.

Figure 33: Distribution of index points per sector



Performing a descriptive analysis of this index, the average score obtained is 0.61, indicating that companies on average have a degree of alignment of about 61% with respect to the guidelines. The median (0.5714), being lower than the average, indicates that the distribution of the index is slightly skewed towards lower values, underlining how a good part of the companies in the sample has a lower alignment than the average.

The mode, having the same value as the median, confirms the result for which the most frequent and significant value is 0.57, reinforcing the belief that most companies are on medium-low levels of alignment.

Looking at the variability of the index, the result of the standard deviation obtained indicates that there is a fair variability in the degree of alignment, however not extreme. Analyzing the percentiles, the first quartile indicates that 25% of companies are placed on a value of 0,57, confirming that a significant part of the sample is in the lower range of alignment. Another confirmation of this comes from the 50th percentile, equal to the median (0.57), suggesting that the degree of alignment is medium-low. The third quartile

(0,71) indicates that 75% of companies obtained a value less than or equal to 0,71 and that only the remaining 25% exceeded this threshold.

Figure 3: descriptive analysis of the index

Mean	0,609
Median	0,571
Mode	0,571
Standard Deviation	0,222
25° Percentiles	0,571
50° Percentiles	0,571
75° Percentiles	0,714

So, in summary, the distribution of the percentiles of the index communicates that there is a strong concentration of companies that stand at medium-low values. The absence of values reaching 100% suggests that companies need to improve their reporting and communication of emissions and related KPIs, however, it should be emphasized that since the CSRD directive is relatively recent, companies still need to understand how to better comply with current guidelines and standards.

With a value of 0.22, the standard deviation indicates that there is some variability in the scores obtained, however not extreme. In addition, a linear regression analysis was conducted, having as a dependent variable the score obtained of the index and as independent variables, GHG emissions, EBITDA, Revenues and finally ROCE[85] were selected to understand whether the score obtained was influenced by any particular variable.

However, the results obtained did not produce any satisfactory value for this analysis. An explanatory table of these results is shown below.

Table 5: regression statistics of index

Regression statistics	
Multiple R	0,332371522

85 ROCE (Return on Capital Employed): it is a financial indicator that measures the profitability of a company in relation to the capital used to generate profits.

R square			0,110470829		
R squared correctly			0,011634254		
Error standard			0,18266023		
Analysis of Variance	**gdl**	**SQ**	**MQ**	**F**	**Significance F**
Regression	5	0,186460966	0,037292193	1,117712031	0,364624138
Residuals	45	1,501414184	0,03336476		
Totals	50	1,68787515			

	Coefficient	**Error standard**	**Stat t**	**Significance value**
Intercept	0,578473339	0,053914182	10,72952084	5,47168E-14
GHG	1,90038E-07	2,30271E-07	0,825282677	0,413564852
EBITDA	3,81928E-06	3,66125E-06	1,043163073	0,302444636
REVENUES	-7,38165E-07	1,07469E-06	-0,686864064	0,495692969
NET INCOME	-3,37024E-06	1,16E-05	-0,290538542	0,772739069
ROCE	0,004842717	0,003652836	1,325741637	0,191616197

As we can see from the results, the R^2 of 0.11 says that this model can explain only a small part of the variance, indicating that the predictors were not able to adequately capture the phenomenon under examination. All independent variables get a very small value, meaning that they have not had a significant impact on the dependent variable, the score obtained. Therefore, overall, this model is not able to explain the variability of the dependent variable, and the p-value of the independent variables, less than 0.05, indicates that there is no significant relationship with the dependent variable. Perhaps with the introduction of new variables, it could improve the significance of the model.

5.4. Final considerations

This chapter provides an in-depth and detailed analysis of KPIs concerning reporting greenhouse gas emissions and sustainability practices, with particular attention to aligning companies with international standards and European regulations.

The analysis highlights a downward trend in greenhouse gas reductions over the 2021-2023 period, with an overall decline of 4.34% between 2021 and 2022 and 1.04% between 2022 and 2023, reflecting the companies' commitment to implementing decarbonization policies and improving energy efficiency,

Furthermore, it must be considered that these reductions may have been influenced by the introduction of the CSRD Directive. However, there is significant variability in progress across sectors and individual companies, with some cases where emissions have not decreased or even increased.

The sectors most responsible for emissions, such as energy, industrial, and manufacturing, are also those that have shown greater commitment to aligning with guidelines and directives. However, a significant gap remains between large companies in these sectors and those in lower-emitting sectors, which often do not have sufficient resources or adequate incentives.

The variability in the adoption of standards, including TCFD, GRI, SASB, and SDGs, represents a further obstacle to the standardization of sustainability reports, which however is not necessarily a disadvantage but makes it difficult to compare data that follows different guidelines. Although efforts have been made to guarantee the interoperability of standards, some uncertainties remain. Thanks to the introduction of ESRS by the European Union, we aim to fill these gaps, but the adoption process will require time and resources.

The analysis highlights that KPIs relating to Scope 1, 2, and 3 emissions are widely reported, while indicators such as avoided emissions and carbon footprint are less monitored, reflecting the practical and methodological difficulties in calculating these indicators, especially along supply chains.

Furthermore, the relationship between emissions reductions and EBITDA performance suggests that, although many companies have invested in sustainability, such investments may have had a short-term negative impact on economic results. This is particularly evident for companies with high emissions, which are facing the upfront costs of transitioning to more sustainable practices.

The raw alignment index constructed in the chapter allowed us to evaluate the degree of compliance of companies with respect to the main guidelines: those in the industrial and energy sectors tend to obtain higher scores, probably due to their greater exposure to stringent regulations. However, the majority of companies analyzed fall within the medium range, highlighting that many key requirements, such as verification by external auditors or monitoring of advanced KPIs, are not yet fully met.

Companies with low scores (<0.6) may be considered behind in the alignment process, often due to structural, sectoral, or resource challenges.

Furthermore, the analysis of the results highlights how the limited use of tools such as internal carbon pricing reflects a lack of advanced approaches to managing emissions. However, the introduction of regulations such as CSRD and ESRS represents an important opportunity to improve the coherence, transparency, and comparability of sustainability reports.

In summary, this analysis highlights the significant progress companies have made in reporting emissions and transitioning to more sustainable practices, but also highlights gaps and opportunities for improvement. Future efforts should focus on regulatory and financial support for less advanced companies, increasing investment in low-carbon technologies, and standardizing reporting practices.

Conclusions

This dissertation investigated the issue of greenhouse gas emissions management and reporting, focusing on current regulations, international standards, and calculation methodologies, which are fundamental to addressing the challenges of climate change and encouraging corporate sustainability. The analysis explored the regulatory and methodological perspective, from CSRD to ESRS, the concept of Environmental Management accounting and its PEMA and MEMA tools, and finally the state of the art literature on carbon accounting, on the benefits and limitations of this practice and future scenarios. In addition, in the last chapter, empirical analysis, a disclosure index was proposed to understand how companies are aligning with the requirements imposed by European legislation while highlighting the major obstacles and opportunities that companies may encounter in monitoring emissions and preparing sustainability reports.

This analysis made it possible to evaluate the practical use of these guidelines and calculation practices, highlighting the importance of harmonizing these tools and regulations to make this information transparent and comparable with each other. In addition, it was observed that the measurement and reporting of emissions, despite being now a globally recognized practice to respond to climate change, is still an open challenge for many companies, especially for those less structured and with capital.

However, the usefulness of monitoring and reporting practices has been proven, showing how they are contributing to the improvement of operational efficiency, the reduction of environmental risks, and the improvement of the company's reputation and image, underlining its strategic power. From a practical point of view, the integration of such management systems is helping companies to stay in line with the growing regulations in this regard, and to fully understand how their impacts are affecting climate change.

CSRD regulations and ESRS standards represent a fundamental first step towards greater transparency and uniformity for emissions reporting, while guidelines such as the GHG Protocol, teach how counting these emissions, dividing them by the three Scopes, and developing KPIs, can help companies understand their impacts. This research has shown how key indicators, such as those related to the monitoring of the three Scopes, or

carbon intensity, can help companies increase environmental performance and set reduction targets. However, empirical analysis shows that the application of such tools is not without difficulties, especially concerning Scope 3, as they require a well-structured and complex approach along the entire value chain.

Another key finding that emerged is the variability in the adoption of these tools, showing that harmonization of these practices is increasingly necessary. To this end, actions have already been put in place to ensure the interoperability of guidelines and metrics, such as the document issued by EFRAG on interoperability with GRIs. In the future, it is of primary importance that companies invest in the training of monitoring personnel, in the use of advanced technologies such as artificial intelligence for data collection and analysis, and finally in strengthening the sharing of information, including with the supply chain.

Efforts to reduce the variability of regulations and guidelines must not stop, as they represent perhaps the first fundamental step to ensure the correct and comparability of monitoring results, helping to create increasingly virtuous and efficient models. However, academic research should focus more on analyzing the influence of emissions on corporate financial performance as this part is the most lacking, as it could help policymakers and companies to find new inefficiencies and points of improvement and strengths.

In conclusion, the monitoring and reporting of emissions should not be seen only as a regulatory obligation or a new source of costs but as an opportunity to improve corporate performance, both financial and operational, and mitigate climate change, while also improving its competitiveness and image with all stakeholders involved.

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