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Enterprise Sustainability Assessment: A review of the literature and a qualitative analysis of twenty-five firm sustainability reports

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Statement under Oath

I certify that this thesis is my own work and that all sources of information used have been fully acknowledged.

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Yorgo Nahas

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Contents

Abbreviations

Abbreviation	Description
AHP	Analytic Hierarchy Process
AOX	Absorbable Organic Halides
CSR	Corporate Social Responsibility
EIO	Enterprise Input-Output
ELCA	Environmental Life Cycle Assessment
ELECTRE	Elimination and Choice Expressing Reality
GHG	Green House Gas
GRI	Global Reporting Initiative
HVAC	Heating, Ventilating and Air Conditioning
ICDP	Industrial Cumulative Degree of Perfection
ICEC	Industrial Cumulative Exergy Consumption
IO	Input-Output
ISO	International Organization for Standardization
IUCN	International Union for the Conservation of Nature
LCA	life Cycle Assessment
LCC	Life Cycle Costing
MAUT	Multi-Attribute Utility Theory
MCDA	Multi Criteria Decision Analysis
MCED	Ministerial Conference on Environment and Development
MDGs	Millennium Development Goals
MFA	Material Flow Analysis
NGO	Non-Governmental Organization
OECD	Organization for Economic Cooperation and Development
PROMETHEE	Preference Ranking Organization Method for Enrichment Evaluation
RM	Risk Management
SCM	Supply Chain Management
SDGs	Sustainable Development Goals
SLCA	Social Life Cycle Assessment
SSCM	Sustainable Supply Chain Management
UN	United Nations
UNEP	United Nations Environment Programme
VOC	Volatile Organic Compounds
WCED	World Commission on Environment and Development

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Abstract

As a result of growing global attention on the concepts of sustainability and sustainable development to meet the objectives that will secure the future of our planet, there has been a specific increasing focus on the companies and organizations around the globe to show their commitment to corporate sustainability. The purpose of this study is to investigate the current state of sustainability performance in firms by exploring the most relevant strategies that are being adopted and analyzing the yearly sustainability reports of twenty-five of the biggest European production companies. Using an extensive and comprehensive analysis of the published 2019 sustainability reports, this study examines the assessment tools and guidelines that were used by the chosen companies and compares them with the information and results found in the literature. The risk management method that is used to measure the severity of a hazard and the probability and severity of adverse effects was found to be the most used assessment tool by the reported companies, while the GRI and ISO 14001 standards were found to be highly adopted by those companies to build their reports. This study definitively gives insights about the current state of sustainability performance in some of the largest production companies and evaluates the quality of the information found in their reports against the required global standards.

1. Introduction

Since the release of the Brundtland Report in 1987, the concept of sustainable development has been playing a crucial role in policy making (Hopwood et al. 2005). In specific, sustainability of firms has become an important research area since firms constitute the productive resources of an economy, and without their support, sustainable development could not be achieved (Chang et al. 2017). Theories explore why and how events occur as a coherent explanation of phenomena. Therefore, theories play an important role in human inquiry which helps us understand, explain and predict phenomena. The consideration of implementing sustainability in firms emerged far before the release of the Brundtland report (Carroll, 1999). Since then, sustainability-related thinking in corporations has matured and many theories have been proposed to explore the complex relationships between sustainability and corporations. Some of these theories include: Corporate Social Responsibility, Stakeholder Theory, and Corporate Sustainability, which are nowadays considered as key advantages of executing sustainability analysis. Since a big number of theories have emerged, future endeavour in the sustainability field needs to be based on clear understanding of the relationships between the evolving theories.

Like in any other research area, and despite the definition of sustainability in the Brundtland Report, the concept of sustainability is still considered to be relatively vague by many which underlies some complexities. In fact, the vagueness of the concept, combined with its expanding importance in national and international policy-making, has led to an extensive debate that led in its turn to wide variety of definitions (Mebratu, 1998). There are approximately three hundred definitions of “sustainability” and “sustainable development” (Santillo, 2007). In addition to the vagueness notion, the concept when applies in firms may lead to many scenarios of tensions and dilemmas, where a company is in a position of conflict between two or many decisions. Those scenarios manifest themselves generally in situations where a financially beneficial decision will hinder the environmental progress of a company, or the opposite where an environmentally friendly policy will negatively affect the financial performance of a company.

Despite the challenges of adopting sustainability in firms, many methods have been and continue to be developed in order to help companies reach their target sustainability performance that will positively impact environment and society. Some of these methods are based on the concept of life cycle assessment, where a product or a material is fully studied from its early production stages to its

final stages, with all monetary and material flows taken into account. This concept encompass techniques such as product life cycle assessment, material flow analysis, input-output models. Other methods are decision-making tools that focus on the analysis of future projects to help managers and decision-makers take the best decisions with least environmental impacts. Some of those methods include multi criteria decision analysis and risk assessment.

1.1. Literature Review

The concept of sustainable development made its first major appearance with the report, *Our Common Future*, that was published by the UN-sponsored World Commission on environment and development (WCED) in 1987. The report was constructed through a global partnership and it was a huge political turning point for the idea of sustainable development (WCED, 1987). At the time, some people expected that sustainable development was no more than a catch phrase will fade slowly with time. On the contrary, the impact of the concept has increased remarkably in national and international policy development, making it the main component of the policy documents of international agencies, business firms and governments. This has led to a widening of the discussion of sustainable development, leading to a wide variety of definitions and interpretations. In fact, the definition of sustainable development used by WCED has been key in developing a "global view" with respect to the future of our planet (Enhert et al., 2015).

The WCED report however, was not the starting point of the concept of sustainability. As any process ruled by evolutionary theory, some remarkable conceptual precursors have been detected. Those precursors have led to the WCED's report and the definition of sustainable development, which in turn was followed by other reports and conferences that promoted sustainability (Hahn and Figge, 2011).

This section focuses on the evolution timeline of the notion of sustainable development. It is classified into four historical periods: Pre-Stockholm (–1972), covering the conceptual and historical precursors up until the Stockholm Conference on Environment and Development, from Stockholm to WCED (1972–1987), Post-WCED (1987–1997) and modern sustainability (1997–Present).

1.1.1. Pre-Stockholm

Thomas Robert Malthus (1766–1834) is considered to be one of the first economists to predict the limits to technological and economic growth caused by resource scarcity. He fits into the classic economics convention, but he is sufficiently at conflict with some basic principles. By 1798, the evil effects of the industrial revolution started to emerge. Poverty, unemployment and disease were already problems calling for mitigating treatment. Contrary to the ideas of William Goldwin (1756–1836) and Marquis de Condorcet (1743–1794), Malthus stated that the vices that plague society are not due to evil human institutions, to the fertility of the human race, which led him to his theory of population (Mebratu, 1998).

According to Malthus' theory, unchecked population tends to increase geometrically, while subsistence tends to increase arithmetically at best. Together with David Ricardo (1772–1823), who agreed with his theory, Malthus conveyed his "environmental limits thinking" in terms of the limits on the supply of good quality agricultural production (Pearce and Turner, 1990). In fact, the fixed amount of land available meant that as the population grows, diminishing returns would tend to reduce the per capita food supply. The living standards would be forced down to a lower level, and the population would cease to grow.

The fundamental deficiency of this theory is that it expects that the total production curve is fixed. In reality, technological innovations, such as fertilizers, have shifted the total production curve upwards, and have increased output per unit of input and offsite the tendency towards diminishing returns. Still, Malthus' theory of "environmental limits" is considered a main precursor to the conception of sustainable development.

Ernest F. Schumacher (1979), in his famous book *Small Is Beautiful* in 1979, addressed the problems of the industrial society and the huge systems of production and consumption. The themes addressed in this book included (McClaughry, 1989):

- Sharp criticism of mega systems as destructive of the planet and of the human spirit alike
- The fast depletion of natural resources and the destruction of the environment
- The Concept of intermediate and appropriate technology, perhaps the thought for which the book is best known for
- The failure of traditional economy to bring "non-economic factors" into the policy-making processes

- Need for human beings to be close to the nurturing land, both factually and spiritually

His effort of looking at the economic, ecological, and social aspects of a given system added new key ways to look at the discussion on the "scale of organisation."

1.1.2. From Stockholm to WCED

The 1972 UN Conference on Human Environment in Stockholm, which recognized the "importance of environmental management and the use of environmental assessment as a management tool" (DuBose et al. 1995), amounts to a major step forward in the concept of sustainable development. Despite the fact that the link between environmental and developmental issues did not emerge greatly, there were signs that the form of economic development would need to be altered.

Around the same time of the Stockholm Conference, a group of illustrious scientists and citizens gathered in Rome and formed the Club of Rome to analyze the global environmental crisis that was expanding at a concerning rate. They wrote a comprehensive report on the state and situation of the natural environment. The report emphasized that the world was going to exceed most of the natural and the ecological limits within a matter of decades, if it continued to promote the same ways of economic growth witnessed in the 1960s and the 1970s (Mebratu, 1998).

After the 1972 UN Conference on the Human Environment, an important concept started to appear which is that environment and development could not for long remain in a state of conflict. In the years that followed, the terminology evolved to new terms such as "environment and development," "environmentally sound development" and "development without destruction." Finally, the term "eco-development" emerged in the UN Environment Program review in 1978, and by this time, it became recognized internationally that environment and development needed to be considered synchronously (DuBose et al. 1995).

According to Tryzna (1995), however, the first major breakthrough came from the International Union for the Conservation of Nature (IUCN). Working closely with the World Wildlife Fund for Nature and The United Nations Environment Programme, IUCN formulated the World Conservation Strategy, launched internationally in 1980, that was a big attempt to merge environmental and developmental concerns into an umbrella concept of "conservation."

Although the expression “sustainable development” did not break through in the text, the strategy’s subtitle, “Living Resource Conservation for Sustainable Development,” certainly highlighted the notion of sustainability (Khosla, 1995). According to Khosla, by introducing the element of time into the development and environment debate, the strategy discovered a truly important factor in sustainability.

The theme was then picked some years later by the WCED. The report of WCED (also known as the Brundtland Commission), *Our Common Future*, grasps the key statement of sustainable development, which is defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (WCED, 1987). According to Kirkby (1995), “this definition marks the concept’s political coming of age and establishes the content and structure of the present debate.”

The conceptual definition of the Brundtland report holds two key concepts:

- The concept of “needs,” particularly the main needs of the world’s poor which needs to be given the overriding priority
- The concept of limitations inflicted by the state of technology and social organization on the environment’s ability to meet present needs without compromising the needs of future generations

By doing so, the report highlights the strong linkage between environmental improvement, poverty alleviation and social stability through sustainable economic growth. Since it can be interpreted in so many different ways, the Brundtland Commission’s definition of sustainable development received a very wide acceptance. This definition can fit nicely into political sound-bites compared with its predecessor’s term “eco-development”; it is in fact something to which everyone can agree (Pearce et al. 1989).

1.1.3. Post-WCED

Since publication of the Brundtland report, sustainable development increasingly has become the main element of environmental discussions, leading to a very wide acceptance with very different interpretations. By 1994 there were more than 80 different definitions and interpretations sharing the center concept of the WCED’s definition (DuBose et al. 1995).

The other major landmark after WCED is the UN Conference on Environment and Development (UNCED), also known as the “Rio Conference,” or the “Earth Summit.” The two-week "Earth Summit" was the pinnacle of a process

that had begun in December 1989, of education, planning and negotiations among all Member States of the United Nations, leading to the acquisition of Agenda 21, an official global consensus on developmental and environmental collaboration. Therefore, preparation for the WCED Conference began in 1989, but it was held in June 1992. Four International Preparatory Committee meetings were held in diverse parts of the world. Parallel to the Preparatory Committee meetings, each UN member country had to construct a national report covering current their national environmental and developmental aspects and preparing a plan for promoting sustainable development in their respective country within the national context (Mebratu, 1998).

Other than the Agenda 21, The UNCED led to production of key international documents such as the Rio Declaration, and conventions on desertification, climate change, and biodiversity. The Rio Declaration had 27 principles on new partnerships and development through collaboration among States, individuals and social sectors (Kirkby, 1995). They reflected human's responsibility for sustainable development, the right of States to use their resources for the environmental and developmental policies, and the need for State collaboration in poverty alleviation and environmental protection. The idea was that States must act in global partnership to protect, conserve and restore the integrity of the Earth's ecosystem

1.1.4. Sustainability Today

The last and newest "era" of sustainable development can be described as the one when sustainability adoption by corporations and organizations have emerged based on defined sustainability goals and guidelines and on internationally set standards that they can now follow.

The start of this new "era" can be attributed to be somewhat around the year 2000, when the United Nation's Millennium Summit established the eight Millennium Development Goals (MDGs), including ensuring environmental sustainability (Haines and Cassels, 2004). In 2002, the World Summit on Sustainable Development was held in Johannesburg to review progress since the Rio conference in 1992, and to agree a new global deal on sustainable development (Waage et al. 2010). This summit gave birth to a new action plan. These MDGs were repeatedly reviewed on intervals in high level meetings in New York in the years 2005, 2008 and 2010 (UN, 2020). After the Johannesburg summit and the interval reviews of the MDGs, another summit was held in Rio de Janeiro in 2012, by

the United Nations Conference on Sustainable Development, also called Rio + 20. One year later, in 2013, two years before the deadline which had been set to meet the MDGs, an event was held in New York, at which member states agreed to summon a high-level summit in September 2015 to adopt new goals which would build on the foundations laid by the MDGs (UN, 2020). In 2015, the Agenda 2030 was determined by the United Nations Summit on Sustainable Development with its seventeen sustainable development goals (SDGs) to replace the MDGs and to provide a set of new universal goals that meet the urgent environmental, economic and political challenges facing the world (UN, 2020).

From all what is presented atop and as a result of growing global attention, focus and efforts to meet the sustainability goals and objectives set, there has been an increasing need for companies, organizations and firms around the globe to show their commitment to corporate sustainability (Enhert et al., 2016). This need increased firstly after the definition for sustainable development that was set by the WCED in 1987, which, though it was given at a societal level, but it "greatly influenced the emergence of definitions of sustainable development at the corporate levels" (Hahn and Figge, 2011). It increased greatly however, after the UN's summit in which MDGs were defined. Those companies, especially large corporations became a key focus of attention in sustainable development (Lozano et al. 2011), since they are perceived generally to be one of the major parties responsible for many negative effects on the environment and societies (Dunphy et al. 2003).

In addition to global pressures on companies to take action in the right direction and commit to sustainable development, it is now recognized that businesses, from all sizes and fields, whether small, medium or large, are "influenced by universal sustainability issues", such as changes in oil prices, growing concerns about staff's health and safety, air, water and land pollution, carbon emissions or the reduction of industrial and commercial waste (Hörisch et al. 2015).

Due to all those pressures and effects that companies can be subject to, companies of all sizes have been challenged to take responsibility for their business activities and the related impacts on the environment and society. Many companies have responded by voluntarily reporting on various aspects of sustainability. Chief Officers, Frontline Managers, and employees have also became more knowledgeable and more proactive, increasingly recognizing their role in contributing to sustainability. In this context, different voluntary tools, approaches, and initiatives have been developed by and for corporations to engage with sustainability (Lozano et al, 2011). This engagement is increasing, as more and more

organizations are willing to report their economic, social and ecological sustainability performance (Schaltegger and Wagner, 2006).

What also enhanced and further engaged companies to take responsibilities in sustainable development is the growth in reporting standards and most importantly the global reporting initiative GRI (Ehnert et al. 2016). In fact, the GRI supplied the first set of guidelines that "not only allowed the comparison of reporting practices by companies around the globe but also challenged companies to report on a range of negative practices by setting clear guidelines". GRI guidelines are now regarded as the main global reporting standard for sustainability by the leading global companies (Hahn and Lülfs, 2014) therefore they are extensively used in the field of sustainability reporting.

1.2. Objectives

This study aims at presenting comprehensive information about the concept of sustainability, its uses in companies and firms, and the current state of sustainability performance in 25 studied production companies. This study wants firstly to let the readers understand the historical aspect of the term sustainability in order to grasp why it became so highly important and required. Then it wants to educate the readers about the tools and methods that companies used and are using in the disclosure of their sustainability performance, as well as the evaluation of their economic, environmental and social impacts. Finally, it wants to put things into perspective by analyzing latest published sustainability reports of production companies whom activities have massive environmental impacts. This study outlines the whole scene of sustainability including the disadvantages and challenges to understand which areas are still unclear and need to be tackled. The proposed assessment methods are the most updated methods that need to be used by corporations in performance assessment. The chosen companies were chosen based on their size in terms of net incomes and operations. For this reason, twenty-five of the highest performing European companies were chosen for the analysis, as results from such companies are more meaningful since 1) they are more likely to be the companies with better assessment and disclosure tools, and 2) they are multinational companies with massive impacts on a worldwide scale, thus they are in more need to be careful and adopting of sustainability assessment procedures.

The novelties introduced by this research are:

- Presenting both benefits and challenges of sustainability reporting, and explaining how to overcome those challenges;
- Summarizing and presenting all the current and most relevant tools and methodologies of sustainability assessment in a clear and concise way;
- Evaluation and assessment of the latest reported sustainability performances of some of the largest European production companies;
- Highlighting what important sustainability data are reported and if present, missing from the companies' sustainability reports;

2. Firm Sustainability

Sustainability has become a significant aspect in managing companies via a holistic approach by considering economic, social and environmental dimensions of companies. With the rising importance of sustainable development, the theories of sustainability in companies have much evolved during the past six decades. Corporate leaders and employees have been constantly recognizing their roles in contributing to sustainability. In this context, different tools, approaches, methodologies and initiatives have been developed by and for corporations to engage with sustainability analysis. Two very important approaches are necessary for all business firms to achieve their target goal of sustainable performance: sustainability indicators and sustainability assessment. Sustainability indicators are linked to sustainability reporting, which is the act of describing a company's current performance by publishing an annual detailed report that contains all the economic, environmental and social data of the company that are measured based on the already defined indicators. Sustainability assessment, on the other hand, is related to the different tools and techniques that companies can use in order to affect their current performance in a positive way (Lozano, 2011).

This chapter is divided into two sections. The first section, named benefits and challenges, offers a critical review of the advantages or strengths of sustainability reporting, possible disadvantages or weaknesses and the type of relationship between financial performance of a firm and its enviornmental performance. The second section, named methodology, outlines the two sustainability approaches used by the companies, presents the most common

assessment tools that are currently implemented and discusses the implications for future sustainability research.

2.1. Benefits and Challenges

2.1.1. Strengths

This subsection offers a critical review of the major advantages of using sustainability analysis in firms. Three major advantages are identified, i.e. the incorporation of Corporate Social Responsibility, Stakeholder Theory and Green Economics.

- Corporate Social Responsibility

  Sustainability related to companies can be traced back to 1930s, when some articles about the social responsibility of business were published. However, the relationship between companies and sustainability was not hypothesized until 1953 when Howard Bowen published Social Responsibilities of the Businessman (Lee, 2008). He argued that big companies were key centres of power, so the strategies and actions of these companies can significantly influence the lives of people in various aspects. Since then, the term "social responsibility" slowly evolved to "corporate social responsibility" (CSR). CSR describes the responsibilities a company should adopt to reach not only economic gains, but also gaisn on the level of society and environment.

  A breakthrough of defining CSR came in 1970, when the Committee for Economic Development (CED) published the book A New Rationale for Corporate Social Policy (Lee, 2008). The book demonstrated that if the surrounding society degenerates, companies will lose their significant support structure. Therefore, it is in the benefit of firms' long-term interests to promote the well-being of society. The nature of CSR can be divided into four categories, i.e. "economic responsibility, ethical responsibility, legal responsibility and discretionary responsibility" (Orlitzky et al. 2003). Social problems are the main topic areas of the responsibilities, including topic areas such as consumerism, discrimination, environment, shareholders, occupational safety and product safety (Horváthová, 2010). Corporate

social responsibility is the strategies a company uses to respond to social issues that are directly or indirectly linked to economic issues.

Currently, one of the most important research areas in CSR is to inspect the effect of CSR on firm economic performance (Tan et al. 2015). For instance, many suggested that there is a clear relationship between corporate social performance and financial performance. The reason is a responsible firm can definitely benefit from its improved reputation in the business community, which improves its ability to attract capital. The relationship between CSR and economic performance of companies is in fact still complex and the debate on this issue is still ongoing. However, despite the uncertainty regarding the effect of CSR on economic performance, the fact that remains is that CSR is an extremely important theory that companies need to adopt in order to safeguard their longevities, as well as the longevity of their respective environments.

- Stakeholder Theory

The stakeholder theory was introduced in the late 1970's (Loorbach and Wijsman, 2013) by Freeman (Freeman, 1984) and it offers a new perspective in theorizing a new role of companies. In his work, Freeman offered that companies had to understand their relationship with not only conventional groups such as employees, suppliers and customers, but also non-conventional groups such as governments and environmentalists to manage their organizations more efficiently. According to Freeman, the meaning of a stakeholder is “any group or individual who can affect or is affected by the achievement of the organization's objectives”. Two types of stakeholders can be detected: primary and secondary stakeholders. Primary stakeholders have a more direct influence or are the ones influenced more by the company (Castka and Prajogo, 2013).

One foundation of the stakeholder theory is that “firms are actors in the social environment and thus should respond to pressures and demands from their stakeholders, to achieve their strategic objectives” (Linnenluecke and Griffiths, 2013). The stakeholder theory suggests that the main obligation of firms is to ensure long-term survival taking into account the needs of multiple stakeholders. Stakeholder theory has notably influenced the CSR research due to the innovative perspective. As a matter of fact, in terms of the construction industry, Zhao et al. (2016) pointed out the key stakeholders of construction companies and developed an indicator system

relying on CSR, which explicitly identifies the suitable indicators for every construction company's stakeholder. To Conclude, Companies and firms cannot reach a high level of sustainable development without taking into account their relationships with all shareholders and stakeholders when it comes to decision making, and this is why it is an advantage to incorporate stakeholder theory as a tool to promote sustainability.

- Green Economics

Green economics play an important role in policy making related to sustainability analysis (Geels, 2012). The concept of green economy was brought into context for the first time in 2005 at the Fifth Ministerial Conference on Environment and Development (MCED) in Asia and the Pacific, since which the significance of green growth and green economy has been more and more recognized in international and national policy making. United Nations Environment Programme (UNEP) defines green economy as the economy which results in "improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (wced, 1987). According to the program, green growth is a pre-requisite for constructing a green economy in the context of sustainable development (UN, 2020). The key assumption of green economy is that nowadays environmental progress cannot be separated from economic development. Green development comes as a result of the investment in the upgrading of the entire production system to reach resource-saving and environmental products and processes (Jänicke, 2012).

Green economics is a pathway to sustainable development since one of the key paths to reach sustainability is to adjust the economy and the way we make investment decisions. This requires substantial usage of market-based and pricing instruments, employment of suitable regulation, supporting policies for voluntary approaches and technology. Green economy policies could certainly change the business environment for corporations since various instruments could be developed to shift investment from environmentally harmful activities to greener industries and businesses. According to Borel-saladin and Turok (2013), all green economy related policies suggest similar measures to ease green growth: 1) Institutions, regulations, norms and behaviour-based policies; 2) Innovation policies; 3) Labour market policies; 4) Agriculture and ecosystems services policies; and 5) Infrastructure, transport and energy policies. Van der Ploeg

and Withagen (2012) argued that green growth will also lead to economic development through several other pathways such as enhanced labour productivity as a result of better health, and enhanced energy efficiency.

2.1.2. Weaknesses

Despite having many external and internal drivers that push companies into moving forward towards sustainable development, some recent research has presented serious doubts on the usefulness of incorporating sustainability in firms (Wannags and Gold, 2020). Until very recently, both researchers and practitioners assumed that firm sustainability goals should aligned with commercial and environmental success. However, many other researchers and practitioners had refocused their attention on the drawbacks of sustainability such as vagueness, tensions, paradoxes, trade-offs, dilemmas and lack of reporting reasons. Those are topics that companies must deal with at different levels when striving towards more sustainable business comportment. The aim of this subsection is to evaluate difficulties faced by companies attempting to transition towards sustainability.

- Vagueness

Sustainable development is a multi-faceted topic which concerns a state, an industry, consumers and citizens. Thus, it has a wide scope which makes the notion quite vague and prone to criticism by many researchers. The concept also comes out of a cross-fertilization of diverse trends: religious and secular visions, industrialism, civil and human rights, mutual funds, ecology, international organizations, and multinational corporate managers, states etc. Therefore, the falsely consensual aspect of the notion is another argument that is contributing to the vagueness of the concept (Pesqueux, 2009).

The notion of sustainable development has also a political aspect, meaning the ethical dimension of the concept definitely loses its important dimension in favor of the political one. Therefore, sustainable development as addressed in companies will tend to face management problems that are likely to persist due to the larger political dimensions.

The notion surrounds already institutionalized projects such as health programs (UNICEF, WHO, etc.) and literacy (UNESCO) which constitute the prerequisites for sustainable development in some way. For

this reason, many researchers suppose that the definition of sustainable development is quite vague and unclear since it is always presented in different terms by different international organizations and programs. The UN for example has provided the following definition: “ability of present generations to meet their own needs by allowing future generations to meet their own needs and aspirations.” However phrases such as acceptable development and notions such as the triple bottom line have emerged and provided other definitions for the term of sustainable development in their own respective ways. In addition, the opposing researchers suggest that the proposed definition by the UN is general and does not facilitate a precise understanding of the notion (Pesqueux, 2009).

All of this generated, the emergence of political, social, and economic awareness on the notion of sustainable development. It is important to note the emotional ambiguity and dynamics of the relationship between the notion and the techniques that must be used to achieve sustainability.

- Tensions, paradoxes, trade-offs and dilemmas

When it comes to companies and firms, tensions exist at multiple levels, occur at the same time, and influence human emotions everytime they result in discomfort, uncertainty anxiety or even paralysis of the actors confronted by them (Putnam et al. 2016).

Researchers such as Haffar and Searcy (2017) found that monetary goals and sustainability goals often conflict each other and that logic does not lead to more sustainable business behavior. Within an active logic, the solution is to eliminate either one of the goals. It is, however, unwise to abandon either the profitability which is the main purpose of corporations or the sustainability factor with all the existing resource limitations and the environmental problems (Rockstrom et al. 2009). Therefore, the paradoxical-thinking perspective is being welcomed as a well-judged response for managing the ambiguous realities of companies and firms committed to sustainable development (Pinto, 2019). On this basis, four terms that represent all the possible corporate contradictions have been identified. Namely, tensions, paradoxes, trade-offs and dilemmas (Wannags and Gold, 2020), explained in the following figure:

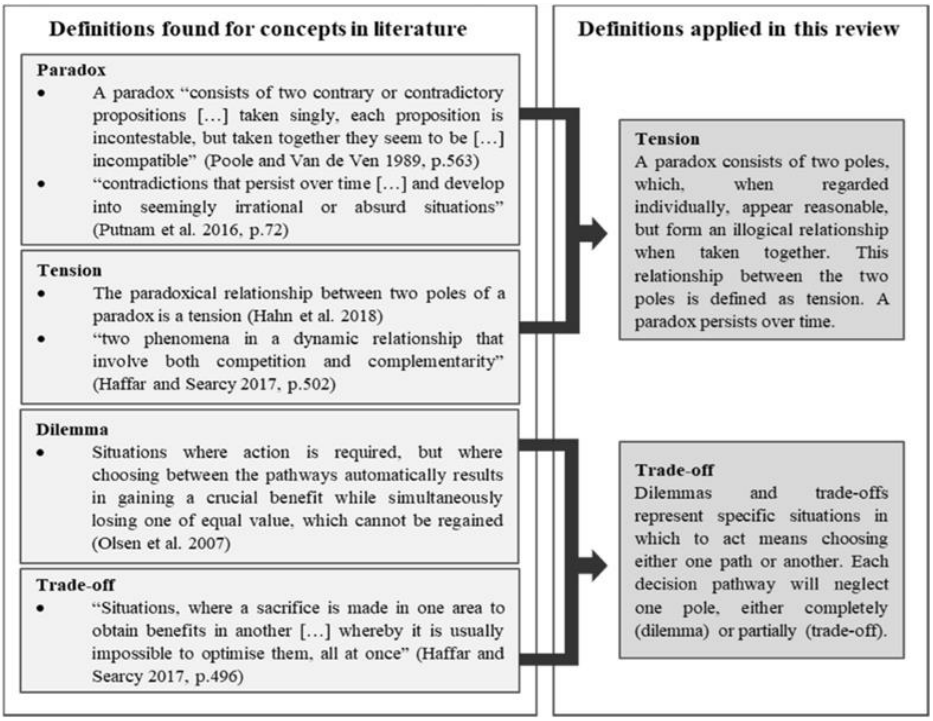

Figure 1- Definitions of tension, paradox, dilemma and trade-off

Furthermore, examinations on tensions inside corporations were made. They result from the analysis of intra-organizational and inter-organizational contexts, because this distinction is important for developing suitable management responses:

Tensions between private and shared values: This tension type takes various forms both intra-organizationally and inter-organizationally. Frostenson and Helin (2017) present the intra-organizational tension between the concept of transparency and the image of an unblemished company in the context of sustainability reporting.

Tensions between individual and organizational agenda: Two actor-oriented situations are identified. Firstly, there are many examples where a less sustainable-oriented organizational agenda oppose a more sustainable-oriented individual agenda: In fact, investigations into the role of sustainability managers in companies have found that these managers may "feel torn between firms' internal logics and the interests and demands of external stakeholders" (Carollo and Guerci, 2017). This tension grows if

these managers get more recognition from external stakeholders than internal stakeholders (Carollo and Guerci, 2017).

Secondly, the other possible situation is illustrated by Christina et al. (2015) in a case study in which a company's organizational agenda is very sustainable-oriented and conflicts with the employees' individual agenda. The reason is that the organizational agenda is looked upon as changing the routines of the employees in problematic ways.

Both examples of tensions between individual agendas and organizational agendas need the attention of the management but in diverse ways.

Tensions between efficiency and resilience: This tension category takes place at an organizational level in the inter-organizational realm. Thapa et al. (2016) propose that the organizational actions that are not coordinated with other organizations would hinder the system's resilience in the longterm. A a matter of fact, Van Bueren et al. (2014) display the poultry production industry as very highly fragmented, with price as the key coordination mechanism and logic for actor behavior, where overall coordination of the chain is not present (Van Bueren et al., 2014).

Tensions between consumers' desire for sustainability and actual unsustainable consumption behaviour: This tension presents "intra-organisational" perceptions into consumers as an actor group. Antonetti and Maklan (2014) have discovered that consumers that are interested in sustainable development can find themselves sometimes in a moral dilemma between their self interest and support for sustainability if there is no sustainable consumption possibility that satisfies their needs. Therefore, the consumer will feel guilty if he decides to choose in favor of his self interest, whereas he will be filled with pride if he decides to choose in favor of sustainability, but then he will fail to fulfill his needs.

- Lack of reporting

Despite substantial academic activity, it seems today that the majority of business companies still do not report their sustainability performance. While 95% of the world's largest multinational companies assume sustainability reporting, only an approximated 2000 or so of 60,000 multinational companies that operate around the world do so (Milne and Gray, 2007). In addition, while sustainability reporting became an aspect of the corporate agenda in the UK, Japan, Australia and some parts of Europe, the majority of large business corporations in these countries still do not

report. In Australia, for example, 77% of the largest top 100 companies produce more than a basic level in their sustainability reporting, but only 47% of the top 200 do so (Australian Council of Super Investors, 2011). A 2008 study of Australian business organizations found that only 126 companies, spanned across a significant range of industries, publish standalone sustainability reports (Higgins et al., 2011). Similar comments were reported in the UK among the biggest 350 publicly listed firms (Martin and Hadley, 2008).

After extensive literature research, four reasons that explain why companies do not issue a comprehensive sustainability performance report were determined: (1) absence of external stakeholder pressure; (2) little motivation to report because of no perceived benefits; (3) sustainability reporting is not a must, but it is nice to do; and (4) organisational structure or culture that is not encouraging sustainability reporting.

1) Absence of external stakeholder pressure: Despite many companies being in industries for which there is wide social and environmental concern, if there is no stakeholder pressure to issue sustainability reporting none of the companies would be motivated to publish the report and no extension to prevailing accountability norms or requirements is essential. Some companies acknowledge that there may be some value in sustainability reporting 'if investors ask for it', in order to evaluate risk (Stubbs et al. 2012).
2) Non perceived benefits: Many companies actually regard sustainability reporting as a waste of time, a distraction to main business, and something that actually offers very few real business outcomes, with very little impact on economic, social and environmental sustainability. This holds true for especially small to medium sized firms, as they think their impact would not be substantial enough to put the effort and issue a sustainability report.
3) Sustainability Reporting is a not a must, but it is nice to do: For many business firms, sustainability reporting is seen as a luxury and not an obligation because the absence of external pressure makes the reporting completely at the dispostion of organisational managers. Therefore, it is organisational imperatives, rather than accountability and social drivers, that influence sustainability reporting decisions.

Organisational structure or culture not encouraging sustainability reporting: For some companies, organisational characteristics play a large part in how sustainability reporting is viewed and understood. Some believe that sustainability is part of their culture and the way they do business but the cultural usuals do not extend to sustainability reporting. Thus, those

companies can be committed to the various components of sustainability and investing their resources for so long, but this does not necessarily mean that they need to issue a report about their sustainability performance. Their idea is that they are contributing to sustainability anyway, so why to tell the world about it.

2.1.3. Financial Performance and Environmental Performance

The relationship between companies' financial performance and their environmental performance has generated a lot of interest between company managers and researchers over the years. This is mainly because it simultaneously addresses two of the three dimensions of sustainability. Despite the fact that both directions of the environmental-financial link are important, the majority of studies have focused on one direction: how does environmental performance affect financial performance (Aigbedo, 2020). This debate has been ongoing for many years and the results have been mixed because they depend on several variables such as industry characteristics, company ownership (private or public), and other things. Some studies such find support for positive impact of environmental performance on financial performance. The basic concepts behind the results of these studies revolve around eco-efficiency by reducing resource use and capital cost from positive images that are portrayed to investors about risk measures of the company (Trumpp and Guenther, 2017). Another reason of the positive relationship is that although investment in environmental programs can be relatively costly, but environmental-related innovations are able to offset the costs invested in environmental programs.

The direction of financial-environmental performance, i.e. how does financial performance affect environmental performance, has also been studied but not as much. The reason is that researchers tend to assume that financial development would intuitively enhance environmental performance due to the higher ability of companies to invest in environmental protection strategies. However, this theory tends to simplify a rather complex subject that depends on many variables. For example, a financial improvement of a company might be a result of the investment in business expansion, and that may leave the company with little to be able to invest in environmental initiatives. For this reason, a study has been done by Aigbedo (2020) by analyzing literature of 468 companies among the 500 developed by Newsweek and its partners: Sustainalytics and Trucost. This sudy inspects how environmental performance can be affected by an improved

financial performance, measured by revenue growth and firm size as a function of number of employees, assets, equity and revenue. The results are represented in the following graphs:

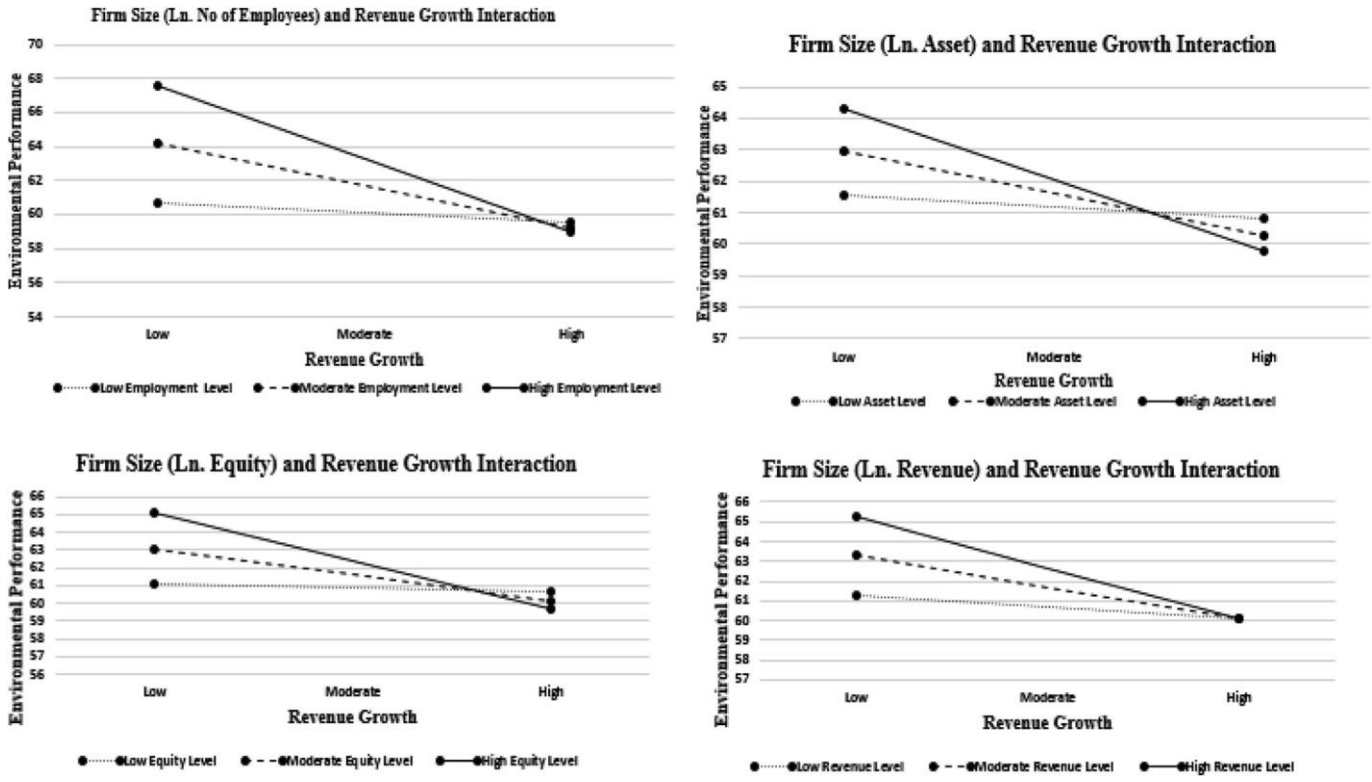

Figure 2- Effect of revenue growth on environmental performance for three firms' sizes measured by number of employees, asset, equity and revenue

The results of the graphs show a negative trend between revenue growth and environmental performance. In other terms, when the revenue of companies have been increasing, their environmental performance have been decaying. The graphs also show that firm size has a direct effect on the trend. When a company is bigger, whether in terms of number of employees, assets, equity or revenue, the trend has always a steeper negative slope than the one for medium to small sized companies. This means that as companies tend to be bigger, the environmental performance tend to decrease much more rapidly with revenue growth. The reason for that might be, in general, that revenue growth serves as a signal for corporations to invest in other useful projects rather than on environmental programs. In addition, small sized companies have a trend that is almost linear which means that their environmental performance is really not affected that much by a revenue

growth. This might be because of the company's small size in the sense that even with a revenue growth, the company is still small enough to be implementing environmental policies, thus their environmental performance would almost remain the same. It is also important to note that when considering firm size by assets and equity, there is a point of revenue growth where small and medium sized companies' environmental performance becomes better than big companies, and this is a result of steep slope of bigger companies regarding to the less steep trends of small and medium sized companies.

The relationship between financial performance and environmental performance will continue to be a very important topic. Since economic prosperity is the main objective of a business company's existence, managers and executives want to know whether or not it is profitable to go green. Usually, most of the researches on this link have evaluated how environmental policies would impact financial prosperity. However, many new researches are emerging currently and are trying to investigate the reverse link. Those link analyses can help managers and executives forge environmental programs that are best for the company.

In fact, understanding the link between economy and environment can be a company's first step towards implementing the right sustainability tool for its financial and environmental benefits. Sustainability assessment tools and indicators are explained extensively in the next section.

2.2. Methodologies

Corporate leaders and employees have been constantly recognizing their roles in contributing to sustainability. In this context, different tools, approaches, methodologies and initiatives have been developed by and for corporations to engage with sustainability analysis. Two very important approaches are necessary for all business firms to achieve their target goal of sustainable performance: sustainability indicators and sustainability assessment. Sustainability indicators are linked to sustainability reporting, which is the act of describing a company's current performance by publishing an annual detailed report that contains all the economic, environmental and social data of the company that are measured based on the already defined indicators. Sustainability assessment, on the other hand, is related to the different tools and techniques that companies can use in order to affect their current performance in a positive way (Lozano, 2011). The next section outlines both approaches and presents the most common assessment tools that are currently implemented in business firms.

2.2.1. Sustainability Indicators

Sustainability indicators are an essential and powerful tool in decision-making for sustainability. An indicator is the operational representation of a quality, characteristic, or property of a given system, by a quantitative or qualitative variable, including its value, related to a reference value. Sustainability indicators are mainly used by business firms and corporations to outline their performance data, and they offer a lot of benefits:

- Sustainability indicators communicate information in a structured way to inform decision-making for enterprise sustainable development
- Sustainability indicators operationalize sustainability. The development of those indicators pushes the discussion of sustainable development away from abstract formulations and encourages clear discussions on concepts with operational meaning
- Sustainability indicators facilitate continuous learning among the stakeholders and their development and application could be a very effective way of social learning
- Sustainability indicators can be used to display accountability to society and its stakeholders by communicating about a company's sustainability performance (Waas et al. 2014)
- Sustainability indicators can be used to identify knowledge and data gaps and suggest priorities for filling these gaps

For these indicators to be reliable and effective to be used in a decision-making process, they should be simple, quantifiable, allow trends to be be determined. They should also be sensitive to change, and permit timely identification of trends (Ness et al. 2006). For that, many international institutions have offered indicators and standards that contain all those attributes for sustainability analysis. The most prominent standards that most companies follow nowadays are the ones produced by the Global Reporting Initiative (GRI) and the International Organization for standardization (ISO) (Pedersen and Esben, 2015), with GRI providing framework for publicly reporting on sustainability while ISO providing guidance on integrating sustainability into a business and its supply chain.

I. Global Reporting Initiative (GRI)

GRI is an independent international standardization organization that helps corporations and organizations be transparent in disclosing their sustainability performance and take responsibilities for their operations and impacts. The GRI was established in Boston in 1997 by the non-profit organizations Tellus Institute and Ceres (the Coalition for Environmentally Responsible Economies) with collaboration with the UN Environment Programme (GRI, 2020). It was founded following the Exxon Valdez oil spill and the environmental damage that was caused. The goal of GRI was to produce the first accountability process that will ensure company commitment to responsible environmental conduct, which was broadened to include economic, social and governance issues. When it was first founded, the GRI produced a set of guidelines for organizations to follow. The first set G1 was published in 2000 at the World Summit for Sustainable Development in Johannesburg, promoting the first international framework for sustainability reporting. The GRI was then established as a non-profit independent institution the following year and then it relocated to Amsterdam in the Netherlands in 2002, at the time when the first guideline update G2 was launched. The demand for GRI reporting from organizations, so the guidelines were improved and led to G3 in 2006 and G4 in 2013 (GRI, 2020). With the growing participation in sustainability reporting by organizations all around the world, GRI started opening regional offices, which led to the current network of hubs being founded in Brazil (2007), China (2009), India (2010), USA (2011), South Africa (2013), Colombia (2014) and Singapore (2019).

The global GRI conferences were held in the city of Amsterdam in 2006, 2008, 2010 and 2016, with more focus on regional or virtual summits since. In 2016, the GRI stopped being just a guidelines provider and transitioned to setting the first global sustainability reporting standards which are today known as the GRI Standards. The Standards always continue to be updated with latest updates being new Topic Standards on Tax (2019) and Waste (2020). Although being independent, the GRI remains a collaborating center of UNEP and continues working in cooperation with the United Nations Global Compact. Currently, there are thousands of reporters in more than one hundred countries around the world. For this reason, the Standards are always advancing the practice of sustainability reporting, and allowing organizations with their stakeholders to take action and make better decisions that benefit everyone (Fuente et al. 2016).

When it comes to funding, the GRI is not tied to any one major funder, which helps it set funding models that allow truly independent reporting standards. The

majority of the funding come from corporate engagements, memberships, commercial services and events, while around 40% come from program grants from foundations and governments. The current GRI funders and the programs supported by them are:

- Department of Foreign Affairs and Trade, Australia
  Sustainable trade and investment through reporting in the Indo-Pacific Region (2017-2020)
- State Secretariat for Economic Affairs, Switzerland
  Corporate sustainability and reporting on the Competitive Business program - phase II (2016-2020)
- Swedish International Development Cooperation Agency, Sweden
  Responsible business for sustainable development: achieving the 2030 Agenda through business reporting (2018-2020)
- Robert Wood Johnson Foundation, USA
  Promoting sustainability reporting to create a culture of health for business (2019-2020)

The GRI's sustainability reporting framework is currently the most widely used by multinational corporations and organizations (Pedersen and Esben, 2015), small and medium enterprises, governments, NGOs in more than 100 countries. In 2017, 75% percent of the Global Fortune 250 which are some of the world's largest companies reported following the GRI reporting framework.

The GRI works with data partners that help in collecting information about GRI and sustainability reporting in organizations. They also help in determining reporting trends in their countries and all information provided by them are included in the sustainability disclosure database of GRI.
Following is the list of all the current GRI standard families (GRI, 2020):

- Universal Standards
- GRI 101: Foundation 2016
- GRI 102: General Disclosures 2016
- GRI 103: Management Approach 2016
- Top-Specific Standards
  GRI 200: Economic
- GRI 201: Economic Performance 2016
- GRI 202: Market Presence 2016
- GRI 203: Indirect Economic Impacts 2016

- GRI 204: Procurement Practices 2016
- GRI 205: Anti-corruption 2016
- GRI 206: Anti-competitive Behavior 2016
- GRI 207: Tax 2019

GRI 300: Environmental

- GRI 301: Materials 2016
- GRI 302: Energy 2016
- GRI 303: Water and Effluents 2016
- GRI 304: Biodiversity 2016
- GRI 305: Emissions 2016
- GRI 306: Waste 2020
- GRI 307: Environmental Compliance 2016
- GRI 308: Supplier Environmental Assessment 2016

GRI 400: Social

- GRI 401: Employment 2016
- GRI 402: Labor/Management Relations 2016
- GRI 403: Occupational Health and Safety 2018
- GRI 404: Training and Education 2016
- GRI 405: Diversity and Equal Opportunity 2016
- GRI 406: Non-discrimination 2016
- GRI 407: Freedom of Association and Collective Bargaining 2016
- GRI 408: Child Labor 2016
- GRI 409: Forced or Compulsory Labor 2016
- GRI 410: Security Practices 2016
- GRI 411: Rights of Indigenous People 2016
- GRI 412: Human Rights Assessment 2016
- GRI 413: Local Communities 2016
- GRI 414: Supplier Social Assessment 2016
- GRI 415: Public Policy 2016
- GRI 416: Customer Health and Safety 2016
- GRI 417: Marketing and Labeling 2016
- GRI 418: Customer Privacy 2016
- GRI 419: Socioeconomic Compliance 2016

II. International Organization for Standardization (ISO)

ISO is an independent, non-governmental international organization with 165 countries with memberships. It is an international standardization organization with representatives from different national standards organizations (ISO, 2020). Through the members, ISO brings together experts to share experiences and knowledge and develop international standards that enhance innovation and provide solutions to global challenges. It is founded in 1949 after 65 delegates met in London to discuss the future of international standardization. Today, ISO has 23511 international standards that cover almost all aspects of manufacturing and technology, and 192 technical committees and subcommittees that take care of standards development (ISO, 2020). Regarding membership, companies or individuals cannot be ISO members, but there are ways that they can take part in developing standards work. ISO members are countries, and there are three member categories: full members, correspondent members and subscriber members. Full members (member bodies) are the ones who can vote in the ISO technical meetings. They also sell and adopt ISO standards nationally. Correspondent members cannot vote but they can still attend ISO technical meetings and see how ISO standards are developed. Subscriber members stay up to date on the works of ISO but cannot participate in it. Regarding funding, ISO's national members pay subscriptions proportional to the country's gross national income that will meet the operational costs of the organization.

Over the years, ISO has developed a lot of international standards that are divided into many families covering all areas of technology and manufacturing as stated earlier, but we will focus in this work on two, which are the families and standards that help companies in their environmental sustainability assessments: ISO 14000 and ISO 50001 families:

- ISO 14000

  The ISO 14000 is the family of ISO that is related to environmental management systems (EMS) that help companies and organizations in managing their environmental responsibilities in a way that contributes to the environmental dimension of sustainability. Inside this family there are many standards, with the most disclosed one by companies being the ISO 14001:2015. This standard specifies what requirements are needed for an environmental management system that a corporation can use to improve the environmental performance. It aids

organizations reach their intended outcomes of their environmental management system, which gives value to the environment, the organization and its stakeholders. The intended outcome of an environmental management system is the improvement of environmental performance, the realization of compliance obligations and the achievement of environmental targets. This standard is applicable to any organization of any size, type or nature. It applies to all environmental aspects of the organization's activities, products and services that it can control or influence. It does not state however specific environmental performance criteria. Other important standards in this family include the ISO 14040 and ISO 14044 which are the reference system in conducting LCAs. Those two standards will be further discussed in the sustainability assessment section (ISO, 2020).

- ISO 50001

ISO 50001 is the family of ISO that is related to energy management systems that is based on the management system model that ISO follows for well-known standards such as ISO 90001 (quality management) and ISO 14001 (environmental management). This standard presents a framework of requirements for companies to develop policies for more efficient energy use, fix the targets to meet the policy, use data to make decisions about the use of energy, measure the results, review if the policy is working and regularly improve energy management. This standard is applicable to any organization of any size, type or nature. It applies to all energy aspects of the organization's activities, products and services that it can control or influence. It is applicable irrespective of the use, quantity or types of energy consumed. It can be used either independently or aligned with other management systems. It requires continual demonstration of energy performance improvement, however it does not define which levels of energy performance improvement to be achieved (ISO, 2020).

2.2.2. Sustainability Assessment Methods

A. Product Life Cycle Assessment

Life Cycle Assessment (LCA) is a method to study the possible environmental impacts and resources that are used throughout a product's lifecycle, from raw material acquisition, via production and use phases, to waste management (ISO, 2020). The waste management phase encompasses recycling and disposal. The term 'product' incorporates both goods and services. LCA is a extensive assessment and it takes into account all aspects of human health, natural environment, and resources (ISO, 2020). The unique characteristic of LCA is the focus on products from a life-cycle point of view. The comprehensive feature of LCA is useful for avoiding hifting problems, for example, from one phase in the life-cycle to another, from one region to another, or from one environmental issue to another (Finnveden et al. 2009).

The first partial studies of LCAs date back to the late 1960s and early 1970s, a period in which environmental problem like energy efficiency, resource efficiency, pollution and solid waste became prominent and a part of broad public concern (Assies, 1991). The scope of energy efficiency, which had been conducted for many years, was later widened to include resource requirements, emission loadings, and waste.

During the 1990s, the world witnessed an impressive growth of scientific and coordination studies worldwide, which is noticeable in the number of forums and workshops that have been organized in this decade (Fava et al. 1993). It was at this time when a remarkable number of LCA guides and handbooks were produced (Hauschild and Wenzel, 1998). In fact, The International Organization for Standardization (ISO) has been involved in LCA analysis since 1994. It adopted the formal duty of standardizing the methods and procedures. There are currently two international standards for LCA:

- ISO 14040 (2006a): 'Environmental management - Life cycle assessment - Principles and framework';
- ISO 14044 (2006b): 'Environmental management - Life cycle assessment - Requirements and guidelines'.

A fundamental result of ISO's standardization was the definition of a general methodological framework.

It is worthy to note, however, that LCA methods were not standardized in detail by ISO: "there is no single method for conducting LCA".

In order to study the life cycle assessment of a product, the three pillars of sustainability defined in the tripe bottom line must be taken into account, hence we should examine the economic, environmental and social impacts of the product:

- LCA = ELCA + LCC + SLCA
- LCA = Product Life Cycle Assessment
- ELCA = Environmental Life Cycle Assessment
- LCC = Life Cycle Costing
- SLCA = Social Life Cycle Assessment

The following sections summarize the state-of-the art with regard to the three dimensions of LCA:

a) Environmental Dimension

Despite their general definition, the international standards ISO 14040 and 14044 are still the main reference system in conducting LCAs. ELCA is a holistic analytic tool and it is now a main and integral part of the known environment management tools. ELCA is differentiated from other environmental assessment tools by two main attributes

- Life cycle perspective:

All phases of the life cycle ("from cradle to grave") of a good or service—from the extraction of the resources, to the production and processing, to the transport and distribution, to the use and consumption, to waste disposal and recycling—have to be evaluated with regard to all possible material and energy flows.

- Cross-media environmental approach:

All possible environmental impacts are taken into account, both from the input side (resource use) and from the output side (emissions, water, soil, waste).

The ELCA is defined as "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle" (Finkbeiner et al. 2010). More information on the present state-of-the-art methodology can be found on the publications pages of the European Platform of Life Cycle Assessment or the UNEP/SETAC Life Cycle Initiative (European Commission, 2020). Apart from standardization, the UNEP/SETAC Life Cycle Initiative plays also an important role in the spreading and distribution of ELCA. A survey has been undertaken to evaluate the development capabilities of ELCA revealed that ELCA capacity of certain levels could be already determined for more than 80 countries internationally (UNEP, 2020).

b) Economic Dimension

When it comes to the economic dimension of sustainability, there are several approaches for the calculation of cost and performance. The economic assessment is usually done by taking into account manufacturing costs (business perspective) and life cycle costs (customer's perspective). The life cycle costs are the total costs of a good or a system, produced over a defined life time (Fysikopoulos et al. 2014). LCC covers all costs without assigning them to a cost unit. A significant challenge for LCC is the different possible perspectives when considering the life cycle costs. The variety of possible perspectives from producer to customer to societal leads to a large number of different methods in costing analysis. As a result, the term "life cycle costing" is mainly used for total-cost-of-ownership evaluations as well as social or external cost assessments. One example of this method is the LCC approach developed by Bubeck (Bubeck, 2002), which considered in affinity to LCA an individual product as a reference object which is already fitting at the stage of product development. This requires a good structuring of all the costs according to stages in the life cycle, a focus on monetary flows (in correlation with material and energy flows) and adopting the perspective of the user of the product.

c) Social Dimension

The social dimension of LCA is interested in the impact of the product on society. The social benefits can be measured by interpreting the effects of the firm and the product on stakeholders at local, national and global levels (GRI, 2020). Social indicators measure the degree to which societal values in the particular areas of life can be reached. However, social indicators are not easy to quantify. Therefore, most of the social indicators that are used contain qualitative standards of activities and systems of the company, including working principles, procedures and management behaviors. These indicators communicate needs that are specific to societal problems such as forced labor and working hours. The topic of SLCA is currently still in development but institutions, scholars and academics are now more and more engaged in SLCA research.

LCA requires a suitable multi-criteria evaluation strategy. Such a strategy has to address the scales and targets of the indicators as well as the weighting of them. For LCA the weighting issue is on at least two levels:

- Weighting of indicators within each of the three sustainability pillars, for example weighting between environmental indicators such as greenhouse gas emissions and waste disposal (the same applies to economic and social indicators)

- Weighting among the three pillars of sustainability (economic, environmental and social).

In the realm of sustainability management, the decision making situations in the field are very diverse. Many objectives and criteria have to be considered in order to settle the number of goals. There are also frequently trade-offs between the goals, which need to be addressed appropriately. The trade-offs between the dimensions of sustainability have to be conveyed with maximum care in order to keep a sustainability balance. Therefore, ignoring the weighting process, which can happen in a real world decision making situation is not a viable option for the development of evaluation strategies. (Finkbeiner et al. 2010)

A general evaluation strategy with model indicators for a LCA is presented in the next figure:

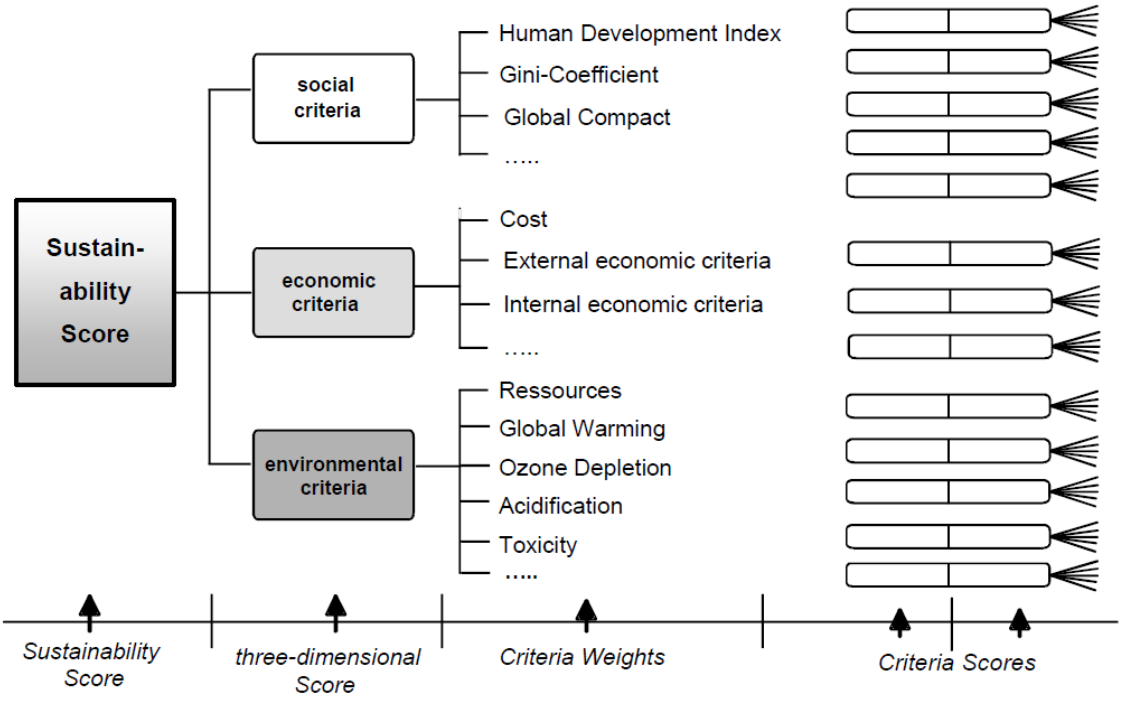

Figure 3- Evaluation strategy for life cycle assessment (LCA) with example indicators

In the end, even though sustainability is nowadays accepted by a huge number of corporations and their stakeholders as a guiding principle, the challenges to determine and measure sustainability performance explicitly does remain, especially for products and their processes. While the environmental

impacts can be measured quite well nowadays, the economic and social impacts and their evaluation methods still need essential scientific progress. This is because the maturity of methods and techniques is different for the three dimensions of sustainability. However, many assessment methods can be useful for supporting sustainable development, if their results are analyzed properly with good consideration of their respective limitations. LCA is ultimately the way to go today, especially for production and manufacturing firms that sell products, because the analysis of the environmental, economic and social impacts of a finished product is relatively easier than measuring the same impacts of a service for example. Still, the life cycle perspective is unavoidable for all sustainability dimensions in order to attain reliable and vigorous results.

B. Material Flow Analysis

Material flow analysis (MFA) is a method that is used to analyze the transportation, transformation, or storage of materials of a defined system (Brunner and Rechberger 2004). It has been applied in various fields, but it is growingly applied in industrial ecology and envionmental analysis (Bringezu and Moriguchi 2002). The increasing use of MFA can be attributed to social-, environmental-, economic-, and health-related demands. One of the main advantages of MFA is that it serves to fulfill higher recycling rates as well as reduce potential losses of secondary raw materials as the European Commission demand (European Commission, 2020).

MFA defines comprehensively and systemically a physical system in order to support decision makers. Up until today, a diversity of MFA techniques has been developed. They differ in terms of (1) scale of the system that is assessed (whole economy, definite parts of the economy, areas or regions, plants, private households), (2) materials investigated (goods, services, substances), and (3) databases that are used (material flows taken from national economic statistics, physical material flows gauged by specific sampling). (Allesch and Brunner, 2015) Regarding the priciple, all MFA approaches are based on the concept of mass balance: sum of all inputs into a system is equal to all outputs plus changes in stocks. The MFA methodology includes the following six basic steps:

a) Objective of the research and selection of monitoring indicators
b) Definition of the system including scope, strengths, boundaries, and time frame
c) Identification of all the processes, flows, and stocks

d) Design of a material flow chart
e) Mass balance
f) Interpretation of the findings and results and conclusion

There is a very close relationship between material flows and sustainable development. In fact, the connections between MFA and sustainable development include the following:

1. Building a systematic database to help map out procedures to improve the efficiency of waste recycling as well as wastes emission and resource extraction.
2. Determining links where inefficiencies in the use of resources or losses occur, and identifying the best materials or products for environmental sustainable planning and management (Laner et al. 2014).
3. Defining meaningful indicators from material flow analysis (Sendra et al. 2007) that are not only focused on enhancing recycling levels but also on promoting smarter resource use (Yabar et al. 2012), hence improving the process of resource extraction and energy use (Recalde et al. 2008)
4. Optimizing the use of materials and their processing by modeling feedbacks of the socioeconomic system to diverse material flow models (Huang et al. 2012). This can be done in the form of a dynamic material flow analysis model (Müller, 2006) or an industrial closed cycle model (Månsson, 2009)

As a result of the previous steps, MFA has the ability to become one of the most important tools in sustainable development assessment. In reality, achievements in MFA today are already challenging conventional economic data for national policymaking in the context of sustainable development (Fischer-Kowalski et al. 2011). In addition, MFA also facilitates the formulation of sustainablity policies, including policies for economy, trade and technological developments, environmental protection, and natural resource management (OECD, 2008).

Material flow analysis differs from product life cycle assessment in that it is an input-output approach that can be applied to a whole system or project, and not only for a single product. It does not take into account monetary flows like LCA, but it only considers material and substance flows. This method would fit really well in a context where there is a company that has waste management or recycling issues. In this case, the MFA method is ideal, however it is not enough and it is better be coupled with other sustainability methodologies in a company in order to tackle all dimensions of sustainability.

C. Energy Analysis

Corporations and business firms are always acting to fulfill the demand of goods and services and they are therefore one of the primary consumers of energy, so it is significantly essential to establish in them sustainability. Reducing the energy demand of companies is an important factor that aids sustainable development because energy usage and supply cause negative environmental effects (e.g., greenhouse gas emissions, acidification, extensive land use…) (Gahm et al. 2015). However, energy is a non-substitutable production factor. This is why reduction in energy demand is limited to a certain extent and is subject to the desired production output. Thus, promoting renewable energy and improving the ratio between energy input and the desired output of a production process, in other terms improving energy efficiency, are some of the key aspects that need to be implemented to achieve sustainability in companies (Fysikopoulos et al. 2014).

Energy efficiency is a relative concept and it has been defined in different ways. It is commonly measured by three indicators: thermodynamic, physical-based, and monetary-based (Zhang and Kim, 2014). The latter is referred to the energy requirement per currency output unit (ex: per unit US dollar output). Physical-based and monetary-based indicators are mainly employed at the macro-level, for instance, when deriving regional or area energy policies (Ang, 2006). Due to carbon emission association with energy use worldwide and owing to growing concerns in what regards global climate change, several indicators, such as energy intensity (energy/GDP), carbon intensity (carbon/GDP) and carbon factor (carbon/energy), have been considerably used for the monitoring and tracking of firm performance in terms of energy efficiency and CO_2 emissions over time (Ang and Choi, 2002). However, in spite of the importance of these indicators, they can still be viewed as only a partial measurement with partial information.

On the other side, and other than energy efficiency, product energy analysis is also another key tool that can be used mainly by production companies. Product energy analysis measures the energy that is required to manufacture a product or a service. It includes both direct and indirect energy flows. Indirect energy is the energy that is used to produce inputs, like the energy that is used to produce metal for the car industry for example. Some of the tools that are used for analyzing product or service energy requirements is Product Energy Analysis. It focuses on the processes and levels in the product life cycle and sums up energy flows through each of the production stages. This analysis is mainly included in the product life cycle assessment method described earlier, as product LCA takes into account all the flows during the life cycle of the product, from economic to environmental to

energetic. In addition to conventional energy analysis, other analyses such as life cycle-based exergy and emergy analysis can also occur. Exergy and emergy analyses have been mainly used for analyzing production processes of a single product as well as entire industries, while exergy analysis also has been extensively used for analyzing energy systems such as heating, ventilating and air conditioning (HVAC) or electricity production. For that, the concepts of exergy and emergy in the production processes should be explained.

- Exergy Analysis

Exergy, *B*, is a measure of the maximum amount of useful work that can be extracted when matter is brought to equilibrium with its surroundings. Energy is neither created nor destroyed, but it is converted from useful to useless as work is done. For example, kinetic energy is converted into dissipated heat through friction as a fluid is transported in a pipeline and in the process, exergy is lost as useful work is consumed or converted. For this reason, exergy is a better measure of the quality of energy than energy because it actually represents the real potential of a system to do work. Therefore, exergy analysis determines how much exergy is consumed in a process and how efficiently the system produces work. Shortcomings of exergy analysis are that it ignores key inputs such as capital and labor, and is limited in scope due to its focus only on the process while ignoring the performance of the rest of the production chain. Extensions of exergy analysis such as Cumulative exergy consumption, Thermoeconomics, and Extended Exergy Accounting (Hau and Bakshi, 2004) address some of these shortcomings. The next figure depicts an industrial cumulative exergy consumption (ICEC) analysis:

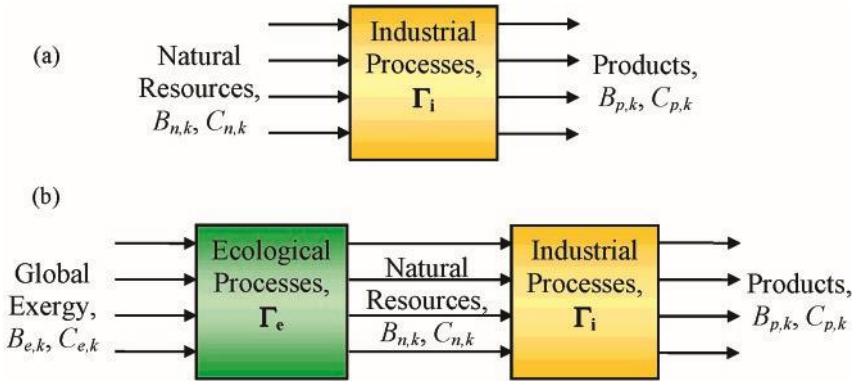

Figure 4- Exergy input/output in industrial and ecological processes

A stream is considered a natural resource if it is a direct product from ecological processes and a raw material for human activities, for example, iron, coal and fresh water. Industrial cumulative exergy consumption of a process is the sum of the exergy of all the natural resources consumed in all the steps of the process and previous processes along the production chain. In general, ICEC of the production chain, C_p, is:

$$C_p = C_n = \sum_{k=1}^{N_i} C_{n,k}$$

where N_i is the number of process units that are included in the industrial production chain, and $C_{n,k}$ and $C_{p,k}$ are, respectively, the cumulative exergy of the natural resources entering and of the products leaving the k-th process unit. To apply the input-output analysis, each unit in the network is considered to have only one external input and output. ICEC analysis considers exergy and cumulative exergy of natural resource inputs to be equal, that is:

$$C_{n,k} = B_{n,k}$$

Lastly, Industrial cumulative degree of perfection (ICDP), η, is the ratio of exergy of final products to the cumulative exergy consumed to make the products:

$$\eta_p = \frac{\sum_{k=1}^{N_i} B_{p,k}}{\sum_{k=1}^{N_i} C_{n,k}} = \frac{B_p}{C_p}; \quad \eta_{p,k} = \frac{B_{p,k}}{C_{p,k}}$$

Where η_p and $\eta_{p,k}$ are the ICDP of the production chain and the k-th product respectively (Hau and Bakshi, 2004)

- Emergy Analysis

Emergy, first noted by Odum in 1980s, is defined as a measure of the total available energy directly and indirectly involved in processes of making a product or service (Brown and Ulgiati, 2010). Emergy analysis is based on the principle of energetic system theory and ecology, which is able to convert different types that have incomparable forms of energy in the ecosystem into a standard energy unit by using diverse transformities to assess the characteristics and eco-economic benefits of the functions and structures of different systems (Wei et al. 2012). The transformity is defined as the amount of emergy of one type that is needed directly and indirectly to generate a unit of energy of another type, and is expressed in solar emergy joules per joule (sej/J) (Yang et al. 2014). As its name implies, the

transformity of a product or a resource t is equal to its emergy divided by the available energy, and a product or a resource's emergy can be expressed as:

$$M = t \times E$$

Where M is the product or resource's emergy (sej) and E is the available energy (J). When an energy carrier flows through an ecological or industrial chain, its exergy per unit of emergy decreases as a result of entropy production along the chain, causing its transformity to increase (Díaz-Delgado et al. 2014). Exergy tends to concentrate as it advances through the chain, and because of that, transformity has been seen as a measure of quality, specifically of ecological products which have been exposed to optimization due to evolutionary pressure. However, the relation between quality of energy and transformity may be much weaker for industrial systems. Therefore, the higher quality of wood versus solar exergy is mirrored by the higher transformity of wood. Many values of transformity have been calculated for ecological and economic goods and services (He et al. 2016)

Recently, and because emergy analysis provides a quantification or valuation of the goods and services embodied in a comprehensive ecological system based on an energy basis, it has been extensively applied in ecosystem assessments, water resources management, and decision-making for regional sustainable development (Nakajima and Ortega, 2015).

In conclusion, whether it is measuring energy efficiency and implemeting new policies to improve it, or undergoing product energy, exergy or emergy analysis to understand the energetic flows and acting accordingly , a company should give an utmost importance to study its energy consumption and implement effective energy analysis strategies in order to reduce as much as possible the environmental impacts of its operations.

D. Input-Output Analysis

Input-Output (IO) models were firstly defined by Wassily Leontief as an accounting system which is identified by a double-entry bookkeeping principle that highlights general equilibrium phenomena (Leontief, 1936). Input-Output analysis is based on input-output tables as an accounting method that helps in answering a lot of questions regarding economy as a whole such as sales and efficiency of production, and how do sustainable policies impact them (Ten Raa, 2006).

Enterprise Input-Output (EIO) approach was introduced in the early 2000s as a tool to analyze sustainability in firms and enterprises along with their supply chains (Yazan, 2015). In fact, each company or enterprise (can be a single company or networks of companies) will be drawn as a black box that takes inputs and transforms them into one or more outputs along with wastes as a result of the transformation. The output that is produced can be a final product or an intermediate input for another company. EIOs are in fact able to model both monetary and physical flows between companies, taking into account wastes, even in case of networks of high numbers of companies implementing the analysis (Albino et al., 2016).

The importance of EIOs stems from them being able to study environmental impacts such as highlighting the carbon footprint or the drivers of waste production and demand, as well as economic and social impacts of the company. In addition, EIOs help companies in implementing impact policies and predicting their outcomes. They have a big advantage because they allow analysis at a high level of detail, since every company can be modeled as built on several production processes, each of them with their specific inputs and producing some given outputs or wastes. They also allow monetary and physical flows between companies to be modeled in the same network (Fraccascia, 2019).

At the level of networks, on the other hand, EIO models can be used to map monetary and physical flows between companies belonging to a supply chain, in order to evaluate the quantity of resources used, and energy consumed and wastes in the system under investigation. In addition to that, and similar to the case of the single company, EIOs help in predicting the impacts and outcomes of policies at the level of networks, and optimize supply chains under environmental restrictions.

Enterprise input–output models are very flexible and generally easy to implement. They help companies and firms in assessing environmental impacts and they measure resource consumption and waste generation (Albino and Kuhtz, 2004). For this reason they serve very well as a planning tool that can be used by managers and public administrators in monitoring the company performance. They are better be used by small and medium sized companies since modelling the inputs and outputs of such companies is not as complicated and time-consuming as the one for big multinational companies that have to take care of hundreds and thousands of flows along their supply chains. In any case, the latter type of companies can easily invest in this analysis due to their resources.

E. Multi Criteria Decision Analysis

Decision-making in companies and organizations requires consideration of trade-offs between political, environmental, economic and social impacts and is usually complicated by many stakeholder views. Multi-criteria decision analysis (MCDA) was born as a formal method to face stakeholder values and available technical information to support decisions in many fields especially in environmental decision making (Huang et al. 2011)

Multi-criteria decision analysis (MCDA), is used to methodology to combine strategies with cost/benefit information and stakeholder views to fianlly rank project alternatives (Huang et al. 2011). There are many approaches and strattegies that all fall under the name MCDA, each involving diverse protocols to define inputs, structures, algorithms, and processes to interpret and use final results in advising and decision making contexts. For example, MCDA techniques have been used to optimize policy selection in the sanitation of contaminated sites by reducing the contaminants entering, the optimization of water resources, and the management of other resources (Linkov et al., 2006). In some of the studies, researchers take into account the opinions of local communities and other stakeholders through surveys or focus groups for example.

The last decade saw an increased interest in the application of MCDA tools with complete and better structured databases. Similar to Linkov et al. (2006), we consider four key MCDA methodologies: MAUT, Outranking (PROMETHEE and ELECTRE), AHP and materiality assessment. These methods share common mathematical relations, since values are assigned for a given number of dimensions, then multiplied by weights and finally combined to build a total score. The methods however differ notably in the details of how values are assigned and combined. The processes used in each method have different information and knowledge requirements and the final scores have slightly different meanings since they have different mathematical properties. Decision-makers often view one of these methods as most appropriate according to the priority they place on its strengths and weaknesses (Figueira et al. 2013).

MCDA Methods:
MCDA methods require as inputs: scores within several dimensions associated with diverse alternatives and outcomes; weights related to tradeoffs within these dimensions.

a) MAUT, or Multi-Attribute Utility Theory. A unitary decision maker who is capable of clearly expressing preferences over gambles and clear tradeoffs

for particular levels of achievement among dimensions. This approach facilitates rational choices, because the course of action with the highest expected utility would be the most preferred option.

b) Outranking approaches, such as ELECTRE (Elimination and Choice Expressing Reality) and PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) are methods that mainly involve holding various “votes” across dimensions. The range of possible scores for diverse alternatives is taken into consideration within each dimension, to derive other alternatives that can be combined across dimensions. An alternative's relative score on a certain dimension is therefore a function of how well it compares against the other alternatives. Then weights are put in application across dimensions to emerge with an overall attractiveness for each alternative. In contrast to MAUT, the scores calculated with this method do not usually aim at identifying a single correct answer, but rather to create a thoughtful process between multiple stakeholders.
c) AHP, or the Analytic Hierarchy Process is a method that uses comparisons of criteria which ask how much more important one criteria is than the other (this is generally easy when multiple stakeholders are involved). The good thing is that AHP can function even with inconsistent or incomplete inputs, to produce weights and overall scores. Like other MCDA approaches, it produces scores for each alternative.

The application of MCDA tools in the environmental dimension has grown remarkably over the last two decades, as we can see from the following graph:

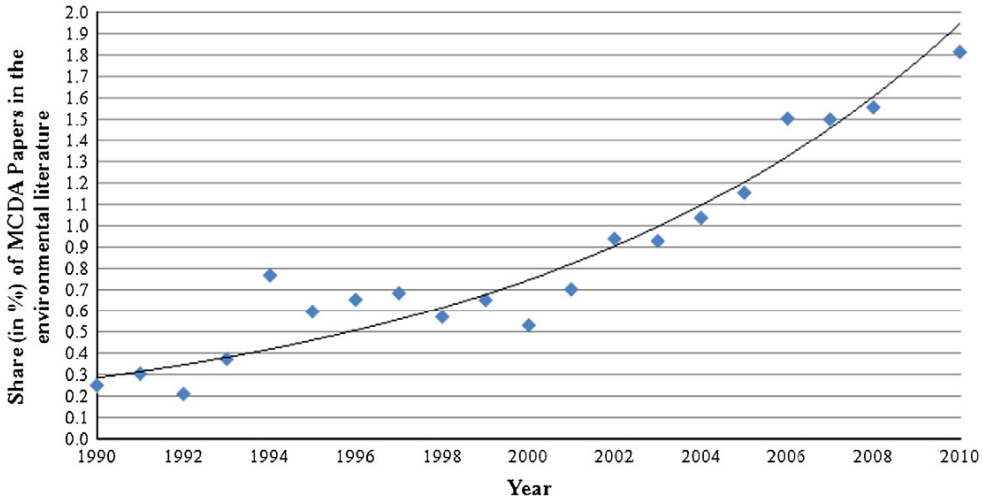

Figure 5- Trend of MCDA papers shared in the environmental literature with respect to time

The reason of this growth can be attributed to an increased decision complexity and information availability, as well as a consistent stakeholders pressure for transparency in the decision-making. Decision analysis using MCDA tools permit the users to solve complicated problems in a technically solid and practically useful way (Cinelli et al. 2014). Therefore, the number of increased environmental MCDA papers is promising, since applications that require integrated environmental evaluation are more dominant due to the interdisciplinary character of environmental problems (Huang et al. 2011).

F. Risk Management

During the last two decades, public interest in the discipline of risk analysis has expanded while risk analysis was born as an effective and comprehensive strategy that complements the overall management of all aspects of life. Managers of all types of companies have incorporated risk analysis in their decision-making process. Moreover the boundless adaptations of risk analysis by many disciplines, along with its classification as a decision-making process by industry and government agencies, have led to an impressive development of theory, methodology, and practical tools (Haimes, 2009).

Risk is defined as the chance that something or someone that is valuated will be negatively affected by a hazard (Woodruff, 2005). The term "hazard" means any unsafe situation or potential source of an undesirable event that can cause harm or damage (Reniers et al. 2015). Moreover, risk analysis can measure the severity of a hazard and the probability and severity of adverse effects (Haimes, 2009). In terms of sustainability, a hazard is any event that can cause damage to the environment and the ecosystem, which can occur in companies that do not manage their operations responsibly (Marhavilas et al. 2011). Furthermore, risk assessment is an important and systematic process for evaluating the impact and the consequences of human activities on systems with hazardous characteristics and therefore, it is a useful tool for the safety policy of a company. Today, more than ever, there are many appropriate techniques and risk analysis procedures for any circumstance. In fact, the risk can be considered as a quantity that can be measured and expressed by a mathematical function, under the assistance of real accidents' data (Marhavilas et al. 2009).

The risk analysis process in a company can be divided into several stages, for that will assist the progress of a supply chain sustainability risk management process. The risk analysis stages are outlined in the following figure:

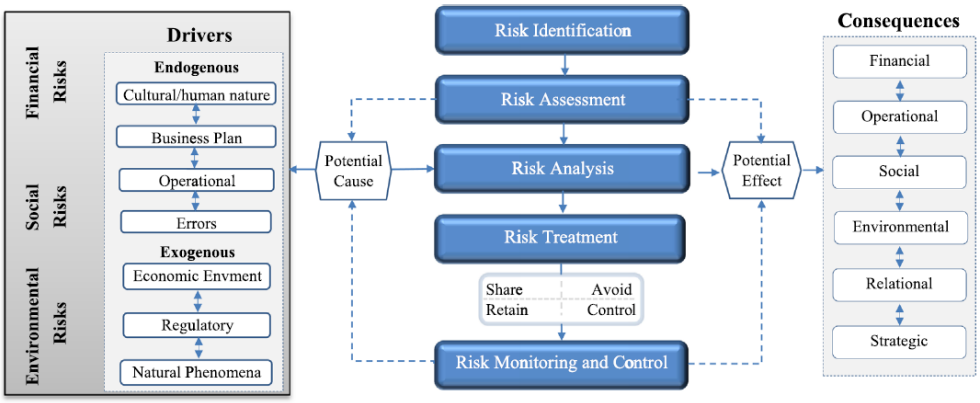

Figure 6- Risk assessment stages

a) Risk identification: This is the first step where we specify all possible supply chain sustainability-related risks using methods and tools such as taxonomies, risk checklists, and risk mapping (Chapman, 2006).
b) Risk assessment: this is the step where all the previously identified risks are assessed and evaluated in terms of the likelihood of occurrence and the

impact on supply chain performance. The methods that are utilized are either intuitive (brainstorming), deductive (hazard investigation, experiments), or inductive (checklists, precursory hazard analysis) (Giannakis and Papadopoulos, 2015).

c) Risk analysis: After being assessed and evaluated, the risks are prioritised in terms of their importance. Then, their possible causes and effects are explored. Cause and effect analysis, root cause and sensitivity analysis or supervised experiments can be used to pinpoint their main drivers and tracks (Hallikas et al. 2010). This step is a very important step in the risk management procedure because if a company understands the main causes and potential consequences of a risk, then it can decide the most significant response. This stage can also involve correlation analyses and simulations to identify possible correlations and causality relations between risks, which is very useful for any risk treatment process as it can tackle two or possibly more risks (Giannakis and Papadopoulos, 2015).

d) Risk treatment: Four main strategies are possible to treat supply chain risks:

- Avoid: Simply avoiding an activity that may lead to vulnerability to a risk, for example not selecting suppliers that do not use sustainable technologies.
- Control: Reducing the probability of a risk event occurring, for example creating a development program that helps in reducing the probability of environmental accidents.
- Share: Cooperating with suppliers to reach risk merging, for example supply chain agreements about the level of ecological or carbon foot print along the entire supply chain (Vose, 2008).
- Retain: Accepting the possible damages that might occur as a result of sustainability-related risk strategy that has smaller cost of potential damage than the other strategies (Vose, 2008).

e) Risk monitoring: This is the final stage and it involves constantly monitoring the effects of the adopted strategies that are used mitigate risks, identifying if there is any change in the supply chains due to their dynamic natures or updating regulations or policies, and then proposing new solutions (Wu and Blackhurst, 2009).

Future research can enhance the current study in several ways. First, risk behaviors and attitudes among different managers can be studied. Risk seeking managers can influence decision making, which plays an important role in the choice of risk strategy. The results can be then be added to the last of methods described in this article to come up with a comprehensive understanding risk

mitigation strategies that should be chosen. Another area of future research could rely on measures such as financial and firm's performance data, to predict the outcomes of sustainability-related risks on firms and then, risks could be prioritized (Surroca et al. 2010).

G. Supply Chain Management

There is a pressure on business firms to consider the entire supply chain when moving towards sustainability in order to reach the desired goals while maintaining their competitiveness. Sustainable supply chain management (SSCM), is defined as the management of flows such as information, material and capital flows and the cooperation between companies along the supply chain while taking into account all three sustainability dimensions, which are gained from customer and stakeholder requirements (Seuring and Müller, 2008). The balance between the three dimensions offers a challenge from the operational to the strategic level. Specifically in the social dimension, there is still a lot of research and we are still far from reaching the sustainable supply chain (Seuring, 2013).

Green supply chain is a term that started being used to define the extension of traditional supply chains to encompass activities that aim at minimizing a product's environmental impact along its entire life cycle, by incorporating techniques such as resource saving, harmful material substitution and product recycling (Mota et al. 2014). The definition of traditional supply chain which is a set of three or more entities that are involved in all the flows from source to customer, set the bounds of supply chain to finish with the final consumer. The green supply does not end with the final consumer, it considers the flows of wastes and disposal products and implements methods and policies for managing and recycling those wastes or products. The outcomes of green supply chain policies is expected to highlight the extent to which green supply chain methods are successfully adopted. Multiple studies have been undertaken to outline the relationship between green supply chain initiatives and performance outcomes but the results are not conclusive. For example, Rao and Holt (2005), and Zhu et al. (2008) found that initiatives of green supply chains have remarkable positive relationship with economic and environmental outcomes of companies, while Vachon and Klassen (2006b) did not find remarkable positive relationships between green supply chain and such performance outcomes. This raises the interest of knowing what actual results can be achieved by adopting green supply chain initiatives.

Green supply chains initiatives can be mainly grouped into the following categories:

a) Eco-design: Activities that focus on minimizing product environmental impacts during their life cycle.
b) Green purchasing: Activities that focus on emphasizing on purchasing items that have desired environmental attributes such as recyclability, reusability and absence of notorious hazardous materials.
c) Supplier environmental collaboration: Activities that focus on improving environmental performance of suppliers and undertaking joint projects for innovating green products.
d) Customer environmental collaboration: Activities that focus on improving environmental performance of customers and undertaking joint projects for innovating green products.
e) Reverse logistics: Activities that focus on taking back products or wasted materials for reuse or recycling.

Those initiatives are expected to create positive environmental outcomes inside and outside organization. Inside organization, they can have notable effects in reducing consumption of hazardous materials and wastes. Outside the organization, they can have significant effects on the natural environment through reducing emissions and managing wastes throughout the life cycle of the product, and reducing the amount of materials and energy used in producing and using those products (Eltayeb et al. 2010)

In addition to having positive effects on environmental outcomes, the literature shows that green supply chains have also positive effects on economic outcomes. For example many have also found significant positive relationship between green purchasing and economic performance by stating that all green supply chain initiatives (Eco-design, green purchasing, supplier and customer environmental collaboration, reverse logistics) positively affect economic outcomes

In the end, it is necessary to note that green supply chain initiatives are one of the most important sustainability methodologies that should be implemented by organizations and companies because it offers an undeniable value for them as well as the external environment. In sustainability analysis it is imperative for a company to consider the whole supply chain from suppliers to customers and not only focus on its activities. Therefore, green supply chain initiatives can play a key role in achieving the “triple bottom line” of environmental, economic and social benefits and, therefore, contributing to the sustainable development of the society.

3. Case Study Definition and Analysis

In this chapter, sustainability reports of twenty-five of the biggest European production companies in 2019 are analyzed to determine the indicators that are used in their reports. The aim of this chapter is to focus on the the type, the number and the diversity of indicators that are presented. The importance of this study is that it gives the readers some insights related to the type of information that are being reported in sustainability reports of famous companies.

3.1. Background Information on Companies Included in the Sample

The companies included in this analysis were ones of the biggest production companies in Europe during the year 2019. During the writing of this thesis, 2019 was the latest year that had available published reports and company data. We limited our scope to only production companies as they are the companies that should mostly be concerned about sustainability issues due to the production nature of their work that affects the environment much more than other types of companies, such as financial, business, insurance or healthcare companies for example. We first took a look at the Forbes Global 2000 website to get an idea of the biggest and best performing firms around the world. The Forbes Global 2000 list is calculated by combining five factors: sales, profits, assets, market value, and number of employees, taken from the yearly reports and balance sheets of the companies. We then filtered the list by continent and by sector, so we chose Europe because we wanted to focus our interest and study on European companies' sustainability performance, and the production sector is chosen for the reasons explained earlier. Forbes Global 2000 served as a primary tool to get an idea and become familiar with what European production companies are the biggest performers financially. Therfore, after looking at the list that we got from Forbes Global 2000, we decided to divide the production companies into 5 sectors, and take 5 of the biggest and best performing companies in each sector to end up with 25 total production companies divided between 5 production sectors. The sectors that we chose are aerospace, automotive, electricity, engineering and oil & gas. The engineering sector covers all the production sectors that are not part of the other 4 sectors, such as construction, steel, chemicals... To select the companies, data from the balance sheets of the 2019 reports were taken into consideration and we

focused on two criteria to determine the 25 companies that we wanted to study: net income of 2019 and availability of sustainability report. In other terms, in order to choose the 5 companies of each sector, we looked at the net income for the year of 2019 as a first criteria, but if the company for some reason did not publish a clear sustainability report, we were looking at another company that maybe had less net income but a clear published report. It is therefore very important to note that the companies present in each of the 5 sectors in the report are not necessarily the eventual top 5 in terms of net income in 2019 for their subsequent sectors because of the other criteria that was considered. They are, however, ones of the best performing European companies in 2019 in their subsequent sectors since they were chosen based on the Forbes Global 2000 that actually gathers data issued by the companies themselves to put up the final list. The idea is not to rank the definite best performing companies by net income as much as it is to rank the best companies by net income that also issued a quality sustainability report. It is also important to note that the German company Bayer is mainly specified as a pharmaceutical and life sciences company but we included it because it is one of the largest German companies so it is interesting to study it and because it produces agricultural chemicals and pesticides which helps in classifying it in the category of chemical companies under the engineering sector. From this analysis, we ended up with the following companies divided by the 5 sectors:

-Aerospace: Airbus, Bae Systems, Dassault Aviation, Leonardo Spa, Rolls-Royce Holdings plc
-Automotive: BMW, Daimler, FCA Group, Groupe PSA, Volkswagen
-Electricity: E.ON, Électricité de France, Enel, Engie, Iberdrola
-Engineering: Bayer, Grupo ACS, Lyondellbasell, Siemens, Vinci
-Oil & Gas: BP, Eni, Gazprom, Shell, Total

All the corporations did provide some indication of the purpose of the report. Some of the stated purposes that were provided describe progress towards targets, provide an update on sustainability programs and initiatives, show how sustainability was included in the business operations, share information on issues of great importance to the company's stakeholders, and reflect on the company's achievements and disappointments.

3.2. Types and Lengths of Reports

The sustainability reports that are analyzed has different titles. Table 1 provides details regarding the variety of studied reports. It shows that almost half of the studied reports were called sustainability reports. Six companies included and reported their sustainability performance inside their annual report which includes in addition to the sustainability performance, the financial performance with all the balance sheets for the specific year.

The mean length of the reports was calculated for each type of report. A summary is provided in Table 1, including the minimum and maximum lengths. There was a wide range of report lengths in the studied sample. Indeed, the longest report was Iberdrola's with 510 pages and the shortest was Siemens' with 64 pages. Because of the extreme values, for most types of reports the mean values were not really relatively close. The typical length of sustainability reports was around 150 pages.

Type of Report	Number of Reports	Mean Length	Maximum Length	Minimum Length
Annual Report	6	269.7	396	212
Sustainability Report	14	157.8	510	64
Corporate Social Responsibility Report	1	308	308	308
Integrated Report	2	108	144	72
Universal Registration Document	2	495	504	486

Table 1- Table showing classification of firms' reports by type

3.3. Indicators Highlighted in the Reports

The reports were manually analyzed to identify the highlighted sustainability indicators. A total of 117 different indicators were reported by the 25 corporations, and they are found in the next table:

Indicator	
Funding, donations, sponsorship and community investments	1
Greenhouse gas/CO_2 equivalent emissions	2
Total employees	3
Taxes and royalties	4
Lost time injury frequency	5
Distribution of donations	6
Total production	7
Employees by region e percentage of local employees	8
Environmental spills and releases	9
Total revenues	10
Number of women	11
Wages and benefits	12
All injury frequency (Number of employee injury incidents per 200,000 hours worked)	13
Energy use intensity	14
Employees with disabilities -	15
Greenhouse gas emissions intensity	16
Regulatory notifications and fines	17
Total assets	18
Water consumption	19
Energy consumption (Production)	20
Net income ($ in millions)	21
Water consumption intensity	22
Electricity use	23
Emissions of sulphur dioxide (SO_2)	24
Employee turnover rate	25
Fatalities	26
Investment in learning/training	27
Sales	28
Solid waste material recycled (t)/reused	29
Women executives	30
CO_2 emissions (direct/indirect/total)	31
Employee satisfaction	32
Reportable environmental incidents	33
Value added and community benefits	34
Disabled in management	35
Earning per share (basic and diluted)	36
Energy saved	37
Health and safety (H&S) incidents	38
Net earnings	39
Breakdown by age	40
Energy use (total electricity and fuel used (TJ))	41
Payments to providers of capital (dividends & interest)	42
Common shares price/value	43
Emissions of nitrogen oxides (NOx)	44
Number of branches/building	46
Total shareholder return	47
Total surface water withdrawal (m^3/yr)	48
Total waste	49
Training hours	50
Total acreage/surface	51
Quantity of waste landfilled	52
Reclaimed product	53
Carbon intensity in product (direct/total)	54
Cash flow	55
Breakdown by gender (in union, management and staff)	56
Energy efficiency plan	57

Number of employees hired	58
Factory audits/workplace inspections	59
Number of unionized employees	60
Total groundwater withdrawal (m^3/yr)	61
Total suspended solids (TSS)	62
Water discharged/waste water overflow	63
Biochemical oxygen demand (BOD)/ chemical oxygen demand (COD)	64
Amount of debt financing authorized	65
Amount of sale of goods and services locally	66
Capital expenditure	67
Contribution to local initiatives	68
Purchase of goods and services	69
Consumption of fossil fuels (Mtoe/Mwh)	70
Medical treatments	71
Paper consumption	72
Earnings before interest	73
Employee compensation	74
Energy consumption (Building)	75
Expenses/expenditure	76
Flaring & venting	77
Hours worked/exposure hours	78
Jobs maintained or created	79
Long-term debt, including current portion	80
Non hazardous waste	81
Injury absences / work absence by leave type	82
Desalination	83
Operating expenses	84
Operating income	85
Ozone depleters	86
Freshwater withdrawal	87
Return on equity (ROE) (%)	88
Sources of GHG emissions	89
Water compliance	90
CO_2 emissions (direct/indirect/total) by sources	91
CO_2 emissions intensity	92
Complaints (nb. or %)	93
Stakeholder engagement	94
Estimated CO_2 eq. annual reduction (tonnes)	95
Fossil fuel use	96
Full time/part time employees	97
Liquidity	98
Market capitalization	99
Number of business clients	100
Number of employees who received training	101
Number of individual volunteering	102
Operating costs	103
R&D spending	104
Shareholder's equity	105
Solid waste disposal	106
Total volume of water recycled/reused (m^3/yr)	107
VOC emissions	108
Amount of debt financing authorized per region	109
AOX (Absorbable Organic Halides) in water	110
Client satisfaction	111
CO_2 emissions from vehicle fleet	112
Distribution line (km)	113
Sox	114
Carbon monoxide (CO)	115
Particulate matter	116
Gender pay gap	117

Table 2- Table showing all indicators disclosed in the twenty-five reports

Basic statistics on the sample reveal that the number of indicators per report varied from 44 for Volkswagen to 84 for Enel. The mean number of indicators per report per report was 63.84. The close values of the mean and the least and

most indicators per report indicate a very small dispersion of indicators within the 25 reports. Now, out of the total 117 indicators, 7 were used only once by one company, and 17 were used by all the 25 companies. The 7 indicators that are only used once are the following:

1) Water consumption intensity
2) Total acreage/surface
3) Total suspended solids
4) water compliance
5) AOX (absorbable organic Halides) in water
6) Distribution line (km)
7) Number of unionized employees

Looking at these indicators, we can notice that the majority are water and ecological indicators that are very specific to the type of activity or project that a company is carrying, hence the reason they are the least frequent. Now, let's take a look at the 17 most common indicators that were used by all the companies:

1) Funding, donations, sponsorship and community investments
2) Investment in learning/training
3) Sales
4) Factory audits/workplace inspections
5) Greenhouse gas/CO2 equivalent emissions
6) Energy consumption
7) CO2 emissions (direct/indirect/total)
8) Emissions of nitogen oxides (Nox)
9) Sources of Greenhouse Gas Emissions
10) CO2 emissions (direct/indirect/total) by source
11) Estimated CO2 eq. annual reduction (tonnes)
12) Total employees
13) Number of women
14) Breakdown by gender (in union, management and staff)
15) Number of employees hired
16) Jobs maintained or created
17) Full time/Part time employees

Here we can notice that all companies have specified some key economic (funding, investments, sales, audits…), environmental (GHG emissions, CO2 emissions,

energy consumption…) and social (total employees, number of women, breakdown by gender…) indicators that are necessary to be reported.

It is important to note that while we were gathering the indicators from the reports, many of them were illustrating similar issues but with different indicators. For example, GHG emissions can be displayed by different indicators such as "CO_2 equivalent emissions", or "CO_2 emissions (direct and indirect)". In such cases, we grouped the indicators that are described by different terms under one indicator name, if it was possible and they shared the same numerical information.

The number of indicators per company is also grouped from highest to lowest, in the table 3, to rank the companies according to the total number of indicators used.

Company	Number of indicators
Enel	84
Iberdrola	83
Grupo ACS	79
Total	78
Électricité de France	77
Groupe PSA	76
Vinci	73
FCA Group	71
Lyondellbasel	71
Bayer	68
Gazprom	66
Rolls-Royce Holdings plc	62
Airbus	61
BMW	61
Leonardo SPA	58
Eni	58
Engie	57
Shell	56
Siemens	54
Bae Systems	53
Dassault Aviation	53
E.ON	53
Daimler	51
BP	49
Volkswagen	44

Table 3- Table showing number of indicators by report

3.4. Types of Indicators by Theme

The 117 indicators can be organized in many different ways. For example, the indicators can be classified according to the three dimensions of sustainability. A total of 35% of the indicators were classified as economic indicators, 42% as environmental indicators, and the remaining 23% were classified as social indicators. This may indicate greater agreement on the core environmental indicators that should be disclosed in corporate sustainability reports.

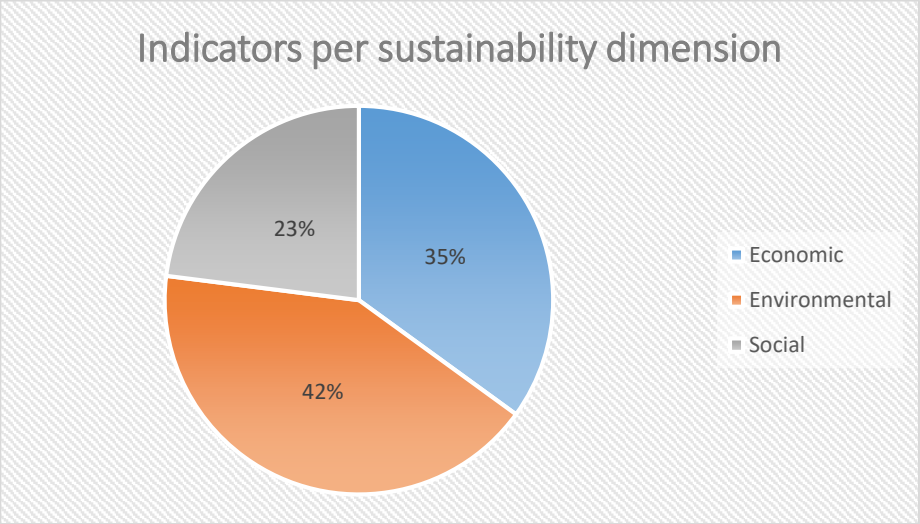

Figure 7- Pie chart indicating percentage of economic, environmental and social indicators

The breakdown of the indicators into the three sustainability dimensions is interesting. However, it is important to recognize that many indicators are applicable to more than one dimension of sustainability. We can therefore categorize our indicators as follows:

- Interaction with community: this category gathers indicators related to community investments, sponsorships, funding and employee personal contributing in charitable works.
- Emissions and effluents: this category gathers indicators that deal with emissions into air (including CO_2 or GHG), effluents, air quality, non-compliances, spills and CO_2.
- Employees: this category gathers indicators that describe ages, headcount, ratio of males and females, training, hiring procedures

and adversity and all indicators related to social profiles within the employee population.

- Energy: this category gathers indicators related to energy consumption, energy savings, energy efficiency, energy costs, and sources of energy.
- Financial: this category gathers indicators linked to statistics on company profile, operating costs and expenses, assets, equity, debts, information on capital, details on shares and shareholders and all financial information.
- Health and safety: this category gathers indicators that detail accidents, risks, exposure to hazards, lost time and medical treatment due to incidents.
- Management: this category gathers indicators related to audits, projects, maintenance, environmental management systems or other management systems.
- Operations: this category gathers indicators that are chosen by companies to describe their main activity. They depend on the industry sector, so they can be as different as number of global chemical consumption and automated banking machines belonging to this category.
- Purchasing: this category gathers indicators that are related to the selection and assessment of suppliers, or the amount of purchased goods and services.
- Research and development: this category gathers indicators that outline the company's interest in research and development such as number of patents and investment in research and development.
- Reclamation: this category gathers indicators that are related to the rehabilitation processes, the status of land and the costs of reclamation.
- Satisfaction: this category gathers indicators that describe the company's image and client or stakeholder satisfaction.
- Service: this category gathers indicators that are linked to services such as online services, interruptions or maintenance of service and customer calls.
- Waste: this category gathers indicators that are related to waste generation, hazardous wastes, landfills and waste diversion.

- Water: this category gathers indicators that highlight water consumption or water treatment processes.

4. Results and Discussion

In this chapter, the reports are qualitatively analyzed to get an idea of how do such companies report their sustainability performance. The aim of this chapter is to study the quality of each report from a sustainability perspective by analyzing the indicators, the sustainability standards, the assessment methods and the strategies that are presented in the reports.

4.1. Indicators

The mean number of indicators per industry sector are given in the following graph:

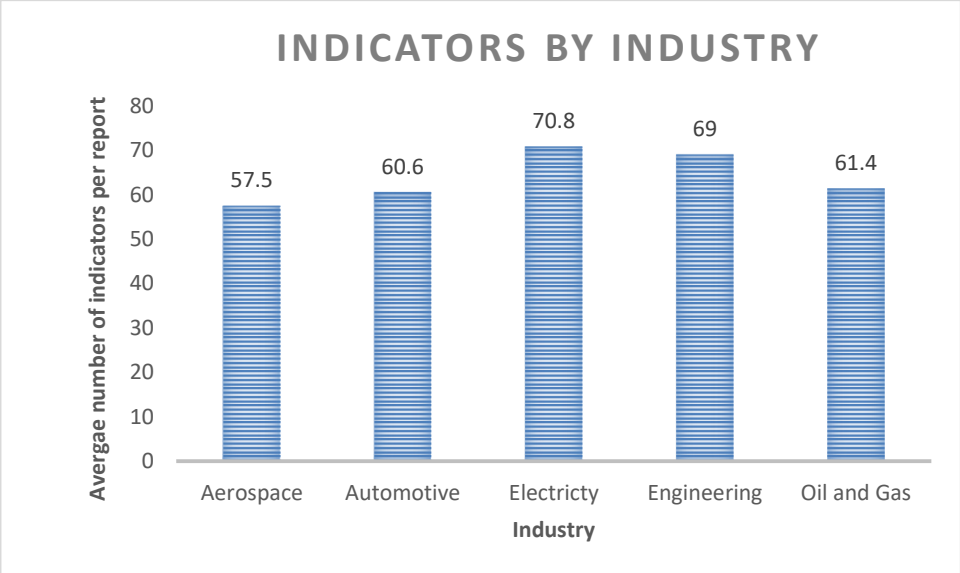

Figure 8- Histogram indicating average number of indicators per industry sector's report

The graph shows that the five electricity and electric utility companies tended to use the highest number of indicators with an average of 70.8 indicators per report. On the other hand, the five aerospace companies tended to present the least number of indicators with an average of 57.5 indicators per report. The graph also shows relatively close values of the mean for aerospace and automotive sectors on one side, and electricity and engineering on the other side.This highlights that these sectors were fairly consistent in the number of indicators used.

Figure 9 below presents a detailed breakdown of the number of times the indicators were presented for each industry sector based on their types. Based on the graph, it can be observed that environmental indicators were the predominant for all but the aerospace sector which presented much less environmental indicators than all of the other industries. This might be because the five aerospace companies work with governments and military so they might not be focusing on environmental issues as much as focusing on production that is linked to political decisions. However, the high number of environmental indicators for all the other sectors means that mainly, production companies are focusing on highlighting as much environmental data as possible to cope with the current international environment of fighting global warming. Between the other four sectors, the companies that are belonging to the engineering sector disclosed the highest number of environmental indicators. Engineering companies also disclosed the highest number of social indicators. For the aerospace sector, the most predominant indicators were the economic ones, which also happens to be the highest number of economic indicators between all the five industries.

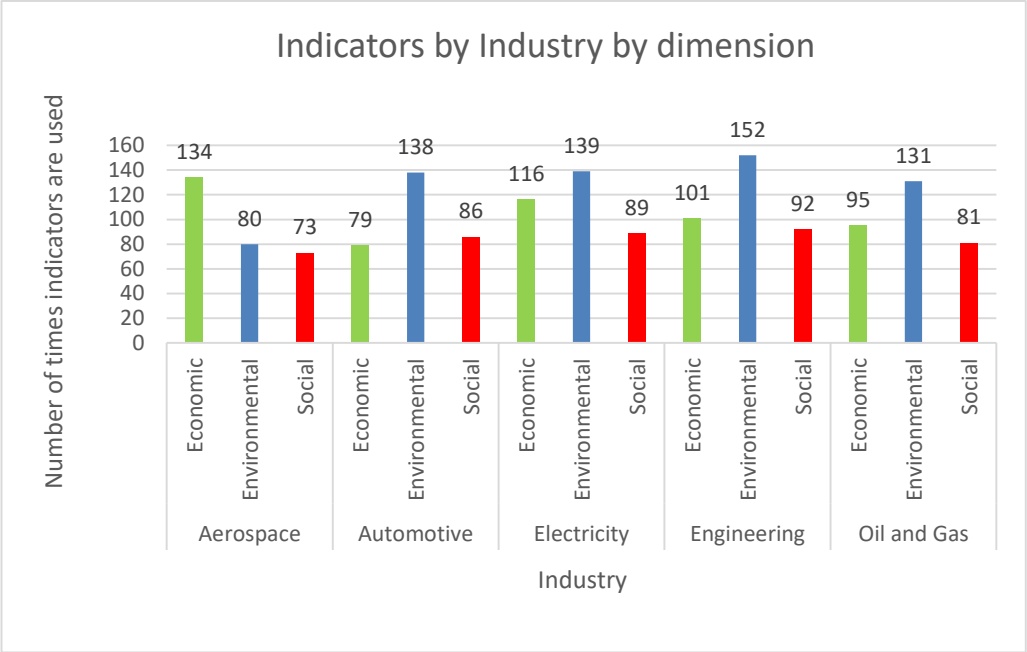

Figure 9- Histogram indicating the number of times an indicator is used by a dimension in an industry

- ## Aerospace Companies

In the aerospace sector, the most used indicators are the economic indicators. The most used economic indicators by the five companies are: funding and investments, taxes and royalties, wages and benefits, sales, and R&D spending. Since Aerospace companies disclosed the most amount of economic indicators, it is important to note which economic indicators were exclusively used by them, which are the following: stakeholder engagement, stakeholder equity and liquidity. It is clear that companies in this sector are specifying more financial indicators related to their stakeholders, because of the large number of stakeholders that are affected by their operations that includes miltary and governments. They are multinational companies that operate and sell aircrafts all around the world, so it is obvious that many stakeholders are affected by their activities. Between the five studied companies, Rolls-royce disclosed the most number of total indicators with 62 total indicators while Leonardo Spa disclosed the most number of environmental indicators with 25 indicators.

- Automotive Companies

The reports of the five automotive companies averaged almost 61 indicators per report, which is the second to last after aerospace companies. With that said, they almost come second in terms of disclosed environmental indicators which means that their social and economic indicators are not abundant. This suggests that automotive companies directed their focus on their enviromental indicators. Some of the exclusive enviromental indicators that are stated in the five reports are volatile organic compounds (VOC) emissions and particulate matter emissions. Other environmental indicators that also all five companies focused on are indicators related to wastes, such as hazardous wastes, non-hazardous wastes, and solid wastes disposals. BMW was the only company between all of the twenty-five studied companies that included the environmental indicator: amount of absorbable organic halides (AOX) in water, while FCA Group was the only group or corporation that included the social indicator: number of unionized employees. Between the five companies the Peugeot Groupe PSA had the most number of total indicators with 76 including the most number of enviromental and economic indicators while FCA Group had the most number of social indicators with 23. On the other side, Volkswagen had the least number of environmental and economic indicators with 20 and 10 respectively, while Daimler had the least number of social indicators with 12.

- Electricity Companies

The reports of the five electricity companies averaged almost 71 indicators per report, which is the highest between all sectors. Despite the fact that they disclose the most amount of total indicators, they come second in the number of disclosed environmental indicators. This sector does not have the most number of indicators in neither one of the three sustainability dimensions, however it does have the most number of total indicators which means that it has the least variance in number of indicators across the three sustainability pillars. This suggests that these five electricity companies are willing to measure and disclose data in all areas of sustainability equally. Some of the indicators that are exclusive and used by all five companies are amount of debt financing authorized by region, emissions of sulfur dioxide (SO_2) and withdrawal of fresh water. Between the five companies, Électricité de France disclosed the most economic indicators with 33, Iberdrola disclosed the most environmental indicators with 37 and Enel disclosed the most social indicators with 22

- ## Engineering Companies

It is important to remind that the engineering sector chosen here includes all production sectors that are not the other chosen four, so the five companies included in this sector in reality belong to more specific sectors such as construction, chemical and industrial manufacturing. The engineering companies specified in this report were the most companies that disclosed environmental indicators, as they were stated 152 times between the five reports. Some of the most stated environmental indicators in this sector were energy consumption of the company's buildings, ozone depleters, quantity of waste landfilled and water discharged per wastewater overflow. Bayer was the only company amongst all twenty-five that reported water efficiency compliance, and Lyondellbasel was the only company amongst all to report total suspended solids. Vinci reported the highest number of economic indicators with 31, Bayer reported the highest number of environmental indicators with 36 and Grupo ACS reported the most social indicators with 22.

- ## Oil & Gas Companies

When it comes to the average number of indicators per report, oil and gas companies come in the middle with almost 61 indicators per report. Some of the most used economic indicators by oil and gas companies are R&D spending. In fact, oil and gas companies were the most companies that highlighted projects that promote sustainability. For example, BP outlined many projects that tend to improve their products by improving the carbon credentials or producing biofuels; Eni focused on projects that maximize energy efficiency and waste-to-fuel projects; Gazprom focused on upgrading the operation units and equipment for better efficiency and reducing gas losses during well surveys; Shell focused on increasing the investments in natural ecosystems and carbon capture, utilization and storage strategies; Total focused on increasing renewable capacities of power generation (solar and onshore wind) and investments in carbon sinks solutions. The number of environmental and social indicators disclosed in each of the five reports are very close, however when it comes to economic indicators, Total disclosed much more than the other four with 36 indicators when the second was Gazprom with only 23 economic indicators. BP was the only company amongst all twenty-five companies to report water consumption intensity.

4.2. Standards

The reports were analyzed in order to determine the companies that followed international standards in their sustainability assessment and reporting. We focused in this analysis on the three most important sustainability standards for companies: GRI, ISO 14001 for environmental management systems and ISO 50001 for energy management systems. The results are shown in the following table:

	GRI	ISO 14001	ISO 50001
Airbus	✓	✓	
Bae Systems		✓	
Dassault Aviation	✓	✓	
Leonardo Spa	✓	✓	✓
Rolls-Royce Holdings plc			
BMW	✓	✓	✓
Daimler	✓	✓	✓
FCA Group	✓	✓	✓
Groupe PSA	✓	✓	✓
Volkswagen	✓	✓	✓
E.ON	✓	✓	✓
Électricité de France		✓	✓
Enel	✓	✓	
Engie	✓	✓	
Iberdrola	✓	✓	
Bayer	✓	✓	✓
Grupo ACS	✓	✓	
Lyondellbasell	✓	✓	✓
Siemens	✓	✓	✓
Vinci	✓	✓	
BP	✓	✓	
Eni	✓	✓	
Gazprom	✓	✓	✓
Shell	✓		
Total	✓	✓	

Table 4- Table showing sustainability standards used by the companies

From the table, we can notice that 22 out of 25 companies did use the GRI standards in developing their sustainability report. This highlights the importance of using these standards in current sustainability reports because they set the outline of a good report and the steps that must be followed. The only three companies that did not specify the use of GRI are the aerospace companies Bae Systems and Rolls-Royce Holdings plc and the electricity company Électricité de France. Those companies did not specify which standards they used in the development of their report. It is worthy to note that the aerospace company Dassault Aviation stated that most of the information found in the report followed the third generation guidelines G3 of the GRI which are not the latest standards but the guidelines published in 2006.

As the GRI, and even more so, the ISO standard for environmental management systems has been mentioned in most of the company reports as only 2 companies did not include it. The companies that did not mention anything about this standard are again Rolls-Royce Holdings plc and the oil and gas company Shell. It is important to note that the ISO 14001 is not a standard used for reporting like GRI, but it is used for assessment. In fact, this standard is a certificate that is granted to either all or specific working sites of a company that a proved a certain level in their environmental managements system implementations. With that said, we will highlight all the companies that do not have all of their plants and production units certified according to the ISO 14001. For Bae Systems, the company's top 10 largest sites, which accounted for 76% of its total energy consumption in 2019 are certified to ISO 14001. For Leonardo SPA, there are 53 certified sites to ISO 14001. For Daimler, 98% of the employees work at locations with environmental management systems that are audited and certified to ISO 14001. For FCA Group, 95 Group plants are certified to ISO 14001. For Volkswagen, 104 out of 124 sites are certified in accordance with ISO 14001. For Total, 281 sites operated by the company are ISO 14001 certified.

As for the ISO 50001, which is the ISO standard for energy management systems, 12 out of the 25 companies that can be shown in Table 4 have stated that they followed it in some of their working sites or plants. Out of these 12, only BMW and Électricité de France have mentioned that all of their plants and business units were ISO 50001 certified. Hence, we will present the sites with ISO 50001 certifications for all of the 10 companies. For Leonardo SPA, 6 sites are certified to ISO 50001 energy management systems. For Daimler, all German production locations and several others outside Germany are certified with ISO 50001. For FCA Group, the plants that accounted for 99% of the total company's energy consumption are certified to ISO 5000. For Groupe PSA, four plants are ISO 50001 certified. For

Volkswagen, 44 production locations are certified with ISO 50001. For Gazprom, an energy management system which is compliant with ISO 50001 standards has been put in place at the company's corporate center, 14 major subsidiaries and upstream and downstream joint ventures. For E.ON, 97% of business units have energy management system ISO 50001. For Bayer, 25% of environmentally relevant sites based on energy consumption have ISO 50001 certifications. For Lyondellbasell, their sites in Germany, France and Spain are certified against ISO 50001. For Siemens, 59 locations have implemented ISO 50001. On another note, Électricité de France stated that they carry out energy audits for their customers in order to help better identify energy savings. The company has certified teams that can assist its customers with the implementation of ISO 50001.

4.3. Assessment Methods

The reports were analyzed in order to determine the sustainability assessment tools and methods that were used by the companies. Four sustainability techniques were found reported in all twenty-five reports: product life cycle assessment (LCA), risk management (RM), supply chain management (SCM) and input-output analysis (IO). The following table lists the companies with the corresponding assessment tool/s that they have used:

	LCA	RM	SCM	IO
Airbus		✓		
Bae systems		✓	✓	
Dassault Aviation	✓	✓		
Leonardo Spa	✓	✓		
Rolls-Royce		✓		
Bmw	✓	✓	✓	
Daimler	✓	✓		
FCA Group	✓	✓		
Groupe PSA	✓	✓		
Volkswagen	✓	✓	✓	
E.ON		✓	✓	
Électricité de France		✓	✓	
Enel	✓	✓	✓	
Engie		✓	✓	
Iberdrola	✓	✓		
Bayer		✓	✓	
Grupo ACS	✓	✓	✓	
Lyondellbasell	✓	✓	✓	
Siemens	✓	✓	✓	✓
Vinci	✓	✓	✓	
BP		✓	✓	
Eni		✓	✓	
Gazprom		✓		
Shell		✓	✓	
Total	✓	✓	✓	

Table 5- *Table showing assessment methods used by the companies*

After extensive analysis of all company reports, we started to get an idea of which techniques are the most disclosed and the most relevant to companies nowadays. As shown in Table 5, all 25 companies have stated that they are implementing risk management techniques as a key assessment tool that needs to be implemented by their sustainability programs. On the other end of the spectrum, only one company out of all of them reported the use of input-output models to calculate scope 3 emissions of the company. Product life cycle assessments and supply chain management come in between with 14 and 16 companies adopting these techniques respectively. More than half of the companies (14) have reported the use of more than one technique, mainly risk management with either life cycle assessment or supply chain management, and 7 companies have reported the adoption of all of them. This fact signifies that the tools are not interchangeable and almost most of the times it is better to apply more than one strategy to cover as much pillars as possible in the

context of sustainability. Only 1 company, which is Siemens, reported the use of 4 sustainability assessment tools adding to the previous 3 discussed before, the input-output assessment tool. On the other side, only 3 companies which are Airbus, Rolls-Royce Holdings plc and Gazprom have reported the use of only one technique which is risk assessment.

In the next part, all 4 assessment techniques were analyzed carefully to understand how each one of them is being reported and implemented by the companies. An examination has been made to check if there is harmony in what regards the steps and procedures adopted for each method between the companies and a summary of all findings will be presented:

- Life Cycle Assessment

When it comes to LCA, most companies that reported the use of this technique were very general and brief in their description. They just mentioned the fact that they used the method in some of their activities. For example, Dassault Aviation reported that the company used life cycle assessment to show that the use of aircrafts accounts for 95% of the company's carbon emissions. Other companies reported stuff like the application of product LCA to all development activities for products that follow the international quality standards. There are however 2 companies that went more into the details of the methodologies of applying LCA and those companies are the Peugeot's Groupe PSA and Volkswagen.

In summary, the 2 companies reported that they observed their environmental impacts over the whole life cycle and all stages of the value chain. This includes the processes of manufacturing with the extraction of raw materials, the manufacturing of materials for the production processes, the processes at their suppliers and their own production at their sites, the usage phase and the ultimate recycling of the product at the end of its life cycle. In the end, hot spots in the life cycle are identified to come up with the best solutions with the greatest possible effect. The LCAs on products and components are conducted within the framework defined in the ISO 14040/44 standards.

The difference is that each company uses a special LCA software with its own LCA database, which helps the exchanging of harmonized data throughout the company and creates a standardized basis for calculating environmental performance.

The reasons for applying LCA studies are many but the most important are:

- Improve the product's environmental record
- Outlining the environmental advantage of one innovative solution over another
- Outlining the overall environmental impact of a product and core environmental impacts
- Highlighting possible pollution transitions from one phase of the life-cycle to another
- Choosing the most environmentally friendly technologies and materials

So we can see from the analysis of the reports of those 2 companies, the stages of the LCA cycle were clearly identified with clear goals and objectives. It is unclear however to which degree the other companies that reported the use of LCA were they involved in the methodology and on which specific processes did they conduct the assessment. It is always preferable to explain a little bit more extensively so the company can remove the vagueness and the ambiguity that were tackled in the previous chapters.

In the end, product LCAs used by production companies are a great method to guarantee that the environmental impacts from a new product are less than those of the previous one. They can also be used at the innovation phase to consider environmental impacts as early as possible.

- Risk Management

It is of huge importance to notice that all of the 25 studied companies have adopted risk assessment and management as a key important part of their sustainability agendas. In fact, not only was the risk management technique implemented, but also its implementation and the steps that were taken were explained in details in all of the reports. Most of the reports had even an entire section depicted for risk management. The reason is that this method is an effective and comprehensive strategy that complements the overall management of all aspects of life. Therefore, managers of all types of companies and especially production ones have incorporated risk analysis in their decision-making process because for those companies, their production processes need to well managed to

avoid any type of hazards. Another reason that explains the huge importance of this analysis is that risk is not related to a certain dimension and can portray itself in many aspects. There are economic, environmental, social and governance risks and their prediction and mitigation is ultimately necessary as the consequences of not considering them can be catastrophic. This defines the fine line between risk management and all of the other assessment tools: risk management is a methodology that needs to be implemented as companies cannot function efficiently without it whereas other tools can sometimes be neglected by some companies simply because their non-implementation would not affect the performance of the company in a negative way, and the cost and time that are needed might not be worth it. For this reason, the reports were analyzed and a summary of the most common steps and techniques used to implement risk management is presented:

Risk owners evaluate the risks, its likelihood and impact, taking into consideration mitigating control activities that identify where additional activities may be implemented to bring the risk down. Risk owners consider the effectiveness of mitigating control activities in their evaluation, supported by diverse assurance providers that include internal audit. Their considerations are recorded by using a variety of tools and methods depending on the risk area. Risk owners then bring the results of their evaluation, current risk status and best plans to business and other management review forums. The results are shared as often as is needed depending on the nature of the risk to support, challenge and supervise. These forums include regular Board and committee meetings. Those are mainly the stages that need to be followed to manage any kind of risk, whether it is economic, environmental, political or a safety risk. Considering the goals of this paper, a focus has been done on investigating the most common ways companies manage climate change risks, and they are specified in the following list:

- Investment in existing products to reduce their carbon footprint, and in zero carbon technologies that can replace the current existing products
- Partnering programs that can introduce skills, capabilities and will to quickly develop the best solutions
- Reducing the dependence on any one customer, product or carbon emitting fuel source
- Clear communication and acknowledgment of each participant’s role in the problem and solution

In the end, risk management is a principal business driver and it is major to the achievement of the long-term business plan of a company. It is usually by companies considered in the core of their sustainability agendas. The success of an organization depends on its ability to identify and capitalize on the opportunities given by the business and the markets in which it competes. By managing the associated risks, a company strives to achieve a balance between its growth goals and the related risks.

- Supply Chain Management

Like the case for LCA, most companies that reported the use of the SCM technique were also general and brief in their description. To summarize, they mainly reported that SCM is implemented by working with the suppliers to deliver aspects of the sustainability agenda. This can be by holding supplier events across the business to facilitate the best practice sharing, encouraging the suppliers to be involved in apprenticeship schemes and career development programs and evaluating suppliers' sustainability performance in the fields of environment, society and human rights with sustainability ratings and showing them opportunities for improvement. The only company that elaborated more and explained about its SCM techniques was the oil and gas company BP.

In its sustainability report, BP stated that it seeks to manage environmental, economic and social impacts throughout its supply chains. The scale and complexity of its supply chains result in activities that need to be managed constantly and responsibly. To provide some insight of the scale of this challenge, the company states that it operates in more than 70 countries and have around 50,000 suppliers. These suppliers include contractors, service providers, vendors and contingent labor, many of whom also have other suppliers. So given the substantial contribution that these suppliers make to the company's activities, they along with contractors play a key part in implementing its strategy to be a successful and strong business. For that, the company engages with the suppliers and contractors to communicate its standards and encourage the best sustainability performance in its supply chains. So whenever possible, BP uses contracts to help secure this is the case, for example by asking from contractors to meet its local workforce requirements for nationals or to support local enterprise. The company thus aims to work with suppliers who strive for adopting sustainability in their supply chains and working with a

sense of innovation and excellence in their delivery of products or services. In fact, all of these requirements are set out in a document issued by the company called supplier expectations document.

In the end, supply chain management is one of the most important sustainability assessment tools that need to be implemented because a company that is willing to promote sustainability will not do so by only focusing on its own activities and neglecting what other impact its suppliers are creating. Suppliers and contractors are critical to a company's ability to run its business because they are involved in almost all steps of its operations. For this reason they are often key to having positive impacts on the community and environment and achieving successful business outcomes. In our assessment, 16 companies have reported that they implement supply management programs but their explanation was brief. It is understandable that following all activities along the supply chain is no easy task as you might be working with suppliers that do not share the same values, but here comes the role of SCM in fixing those situations, promoting sustainability and affecting the supply chain to follow.

- Input-Output Analysis

In this section, not much can be said and analyzed as only one out 25 companies, Siemens, has reported the implementation of this technique. In fact, even Siemens just provided a quick glance about their use of the input-output analysis. The company stated that they have used a multiregional macroeconomic input-output model on the basis of their volume of purchases goods and services to calculate scope 3 emissions, which are the indirect emissions that occur in the value chain of a company, including both upstream and downstream emissions. Indeed, data regarding scope 1 and scope 2 emissions are easier to get as they are related to the direct emissions and the indirect emissions that are coming from the generation of purchased electricity. However, when you start considering emissions coming from the value chains, input-output models are ones of the best tools that serve best for such analysis and for situations where flows of energy and materials need to be estimated.

It is important to note that although the input-output analysis was mentioned by one company, many consider this technique a part of the life cycle assessment method. So this suggests that there is a very high possibility that some of the companies that reported the adoption of the

life cycle assessment method in their sustainability reports are actually using and implementing input-output analyses but they just did not explicitly report it. Another important note is that if we were to suggest that input-output analyses are great for assessing scope 3 emissions based on the report of Siemens, then there are some other companies such as Eni for example that also reported their scope 3 greenhouse gas emissions, so a hypothesis can made that these companies might also be using input output models, but again they did not mention or report anything related to this analysis.

4.4. Strategies

In this section, the aim is to showcase the major strategies that are proposed by the companies to withstand and promote their sustainability performances. The focus will be on the strategies that will tackle the environmental and reduce environmental impacts of a company in the future. After all, environmental strategies are the core and the nucleus of each company's strategy plan, as climate change is the most relevant and alarming global issue today. It is necessary to note that there are many strategies and plans that have been reported that might differ by name and but have the same concepts and goals, and therefore they can be summarized in a list of most common and similar strategies and future plans. A list of strategies will be provided in order to understand the current path that the studied companies are willing to take to fight the global environmental problem. The strategies are divided into 3 categories: energy strategies, emissions strategies, and ecological strategies.

- Energy Strategies

  - Promoting projects aiming at backing and promoting electric vehicles that are used as company fleet
  - Upgrading heating, smart lighting, and ventilation energy systems
  - Improving energy management system by doing internal audits and continuous training of specialists in energy saving and energy efficiency
  - Improving energy efficiency of a company's assets by monitoring of electricity use and making units and equipment more efficient

- Collaborations with communities on district heating and promoting co-generation power plants at the company's projects
- Increasing renewable capacities of power generation by adopting operating onshore wind power, solar, hydroelectric and biogas projects
- Developing renewable electricity generation programs by proposing decentralized photovoltaic systems for industrial and business customers
- Developing electric and gas mobility programs, which develop products tailored to all vehicles with electric hybrid or gas engines
- Developing energy management and services programs that develop products and services that improve energy efficiency and provide opportunity to affordable low-carbon energy with operational flexibility
- Promoting and supporting the role of hydrogen in the energy transition

- Emissions Strategies

- Establishing carbon neutral sites
- Pushing low carbon accreditation programs that aim to inspire the company to identify lower carbon opportunities
- Investing in low carbon activities including renewables businesses and acquisitions
- Investing in technologies of biofuels as they have life cycle GHG emissions around 70% lower than conventional fuels
- Setting business models that follow a path of decarbonization with ambitions to lead the company towards carbon neutrality in the long term
- Updating every year the policy of reducing greenhouse gas (GHG) emissions
- Conducting activities to reduce air pollutant emissions, including the replacement of less sophisticated equipment with new technologies
- Allocating part of the R&D on initiatives and groups that promote carbon capture, utilization and storage
- Supporting the European Commission's proposal for the EU to reach net-zero emissions by the year 2050
- Investing in natural carbon sinks solutions
- Promoting programs that aim at minimizing and then eliminating GHG emissions from the company's industrial sectors
- Aiming at reaching 100% certifications of ISO 14001 in all company sites and operating units

- Ecological Strategies

  - Enhancing recycling technologies designed to turn difficult-to-recycle plastic waste into recycled feedstock that can be used in new plastic packaging
  - Supporting waste-to-fuel technologies and projects that convert rubbish and waste into fuel for transport
  - Reviewing water risks every year, taking into consideration quality, quantity, availability, and regulatory requirements by using a range of tools
  - Developing of forestry projects for forest conservation that will also contribute to carbon capturing
  - Formalized commitments not to carry out development activities and exploration in UNESCO world heritage natural sites
  - Increasing investments in natural ecosystems that produce carbon credits to help drivers in key markets to offset their carbon emissions

Let's take a look at the most common strategies by industry:

- Aerospace Companies

  For the five aerospace companies studied in this research, the most common strategies that they focused on were related to controlling the environmental impacts of the products throughout their life cycle, and investing major efforts into inspecting and reducing the impact of the products in operation together with the actors in the aviation sector. These companies are focusing on collaborating with their worldwide supply chains by building sustainable relationships based on mutual interests to reach more effective environmental management, decarbonize their industry and satisfy their customers to encourage responsible practices. In addition, aerospace companies place innovation at the core of their effort by investing in research and development and new and sustainable technologies to help reach their visions.

  Some of the strategies that companies in this sector are focusing on are improving energy efficiency of a company's assets by monitoring of electricity use and making units and equipment more efficient and allocating part of the R&D on initiatives and groups that promote carbon neutralization.

It is therefore shown that aerospace companies' main focus area in promoting sustainability is the development and innovation of their products and technologies in a way that reduces emissions and environmental impacts of these products.

- Automotive Companies

For the five automotive companies studied in this research, the most common strategies that they focused on were related to climate protection and air quality by increasing their research in electromobility and working on decreasing the emissions of their vehicles. In this process, their work focuses on electric, connected and autonomous vehicles as well as less polluting petrol or diesel vehicles and is geared to their customers' needs. They also focus on reducing the CO_2 emissions of their vehicles along the entire production value chain. The vehicle's environmental impact is largely determined during the first phases of the development and that includes the emissions of pollutants. For this reason, strategies related to these companies tend to focus on taking environmental impacts into consideration as early as possible in the development process, because the earlier the more efficiently they can minimize the impacts of the vehicles.

It is therefore evident that for automotive companies the focus is on two areas of action: 1) products and services, and 2) production and value creation.

1) Products and services: related to projects that aim at reducing the CO_2 and pollutant emissions of the vehicles that are being developed and taking a holistic approach to promote premium electromobility that do not have negative environmental impacts.
2) Production and value creation: related to reduction of resource consumption (energy, water, solvents, waste for disposals) per vehicle produced, the use of renewable energy in value creation and production and the increase in supply chain transparency and resource efficiency.

- Electricity Companies

For the five electricity companies studied in this research, the most common strategies that they focused on were related to energy networks and customer solutions, i.e. making the energy system more efficient and increasing the proportion of renewables in the energy mix. This is done by focusing on smart distribution networks and new innovative customer solutions that make the countries where they operate climate friendly, more energy efficient and sustainable. Those distribution networks are formed of wind and solar farms, battery-storage systems and other climate-friendly technologies that are connected to the distribution grids. Going forward, smart grids will be the transformative platform for the innovative business models and technologies that are essential to the energy transition's success. The energy sources in the distribution systems are becoming more numerous, smaller and renewable with aid of advanced technologies that help to predict fluctuations in renewables power output as well as consumers' energy demand. The energy storage will be increased in capacity which will enable the energy system to harness more clean energy, and one important source for this increase in capacity will be the use of electric vehicles.

To be able to promote distribution energy systems and smart grids, those companies start from strategies on a smaller scale that will help achieve the implementation of the smart power networks. Some of these strategies are promoting projects aiming at backing and promoting electric vehicles that are used as company fleet, improving energy management systems by doing internal audits and continuous training of specialists in energy saving and energy efficiency and improving energy efficiency of their assets by monitoring of electricity use and making units and equipment more efficient.

- Engineering Companies

For the five engineering companies studied in this research, it is important to remind that the companies are actually part of different sectors that can be classified under the general engineering sector. However, after extensive analysis of the reports, the studied companies showed a lot of commonalities in what regards their goals and strategies that they are willing to implement to promote sustainability. The most

common strategies that they focused on were related to monitoring the impacts on climate change from their activities, products and services in order to avoid or minimize the GHG emissions. This is done by setting GHG emissions reduction targets that are aligned with the latest trends and targets, establishing new mechanisms for managing energy use and emissions to measure performance and decision-making and identifying the available opportunities for promoting environmentally friendly products and services that are adapted to the impacts of climate change and contributing to the transition to low carbon economies. In addition, there has been a lot focus among the five studied engineering companies on ecological issues and the decisions and goals that need to be set to solve those problems, such as reducing wastes and conserving natural ecosystems.

As it was said before, the five engineering companies belong to different sectors, but the strategies that were presented were in the major part quite similar in their objective. However, this does not refute the fact that there were a lot of strategies and we will present the ones that were mostly emphasized on: upgrading energy systems; collaborations with communities on district heating and promoting co-generation power plants at the companies' projects; developing energy management programs that develop products and services that provide opportunity to affordable low-carbon energy with operational flexibility; pushing low carbon accreditation programs that aim to inspire the companies to identify lower carbon opportunities; replacing less sophisticated equipment with new technologies; enhancing recycling technologies designed to turn difficult-to-recycle plastic waste into recycled feedstock that can be used in new plastic packaging; supporting waste-to-fuel technologies and projects that convert rubbish and waste into fuel for transport; increasing investments in natural ecosystems that produce carbon credits to help drivers in key markets to offset their carbon emissions.

- Oil & Gas Companies

For the five oil and gas companies studied in this research, the strategies that they focused on were so diverse ranging from carbon neutralization policies to power production from renewable energy. In fact, the five companies that are correspondent to this sector disclosed the most amount of strategies that they are willing to undertake among all five

industries. The reason might be that there is more pressure on this sector to show support on climate change and global warming issues since it is the sector that is responsible of extracting fossil fuels and producing crude oils and natural gas, all of which are regarded as the sources of energy that advocate global warming and devalue environmental sustainability. For this reason, the five oil and companies wanted to demonstrate in their sustainability reports that they are willing to put a lot of work on enhancing their sustainability and adopt countless strategies that actually hinder the negative environmental impacts of their production.

BP for example directed most of its focus on accrediting lower carbon technologies and engaging its employees in advancing low carbon transportation. Its goal is to reach net zero across its entire operations on an absolute basis by 2050 or sooner and 3.5 million tons equivalent of sustainable GHG reductions by 2025. For Eni, the main focus was on developing new technologies that aim at capturing CO_2 by developing forestry projects for forest conservation and on maximizing the energy efficiency of its assets by growing low carbon and emission-free sources in its portfolio. Its goal is to reduce upstream GHG emissions intensity index by 43% by 2025 and to reach 52% emissions reduction in 2040 vs. 2018. Gazprom focused mostly on hydrogen projects to demonstrate how natural gas can be used in low-carbon power generation such as production and use of methane-hydrogen mixtures for own energy needs, and the replacement of less-sophisticated technologies by more developed and less polluting technologies. Shell focused on offering lower-emission energy products including natural gas, biofuels, hydrogen and renewable power and adopting projects that focus on carbon capture, utilization and storage, methane detection and reduction, as well as energy efficiency. Its main goal is to cut the intensity of greenhouse gas emissions of the energy products they sell by about 50% by 2050, and 20% by 2035 compared to their 2016 levels, towards meeting the goals of the Paris Agreement in keeping the increase of global average temperature to below 2 degrees Celsius (UN, 2020). For Total, the main focus is on increasing renewable capacities of power generation and developing an integrated approach to the generation of low carbon electricity by developing and operating onshore wind power, solar, hydroelectric and biogas projects inside Europe, and proposing decentralized PV systems for residential, industrial and business customers outside Europe. Its main objective is to reduce the carbon intensity of the

energy mix that they offer to their customers by 15% by 2030 and 40% by 2040.

It is shown therefore that oil and gas companies are willing to invest in countless projects and implement many strategies that are environmentally friendly, in a way to ensure their sustainability and possibility of operation in the future without having to deal with the negative impacts of their activities and the international pressure that develops from them.

5. Conclusion

Nowadays, there is a lot of focus on the subject of sustainable development by many national and international organizations as a key concept that must be adopted by each and every working entity to insure the continuity of its activities without hindering its abilities of operating in the future. This study helped provide insights into sustainability reporting, indicators, assessment methods and the way these tools are used by twenty-five large European production companies, after introducing and explaining the most relevant tools and techniques that must be adopted. The research showed that the indicators that were disclosed were distributed along the three dimensions of sustainability, with greater focus on the economical and the environmental aspects, and less focus on the social one. This underlines the difficulty of developing a standard set of social indicators that are quantitatively measured. The research shows that most companies have mostly disclose environmental indicators, which suggests that the companies are aware of the environmental consequences of their activities and why it is so important to monitor them.

Most of the companies that were chosen for the study have reported that the GRI standards served as the main guidelines and foundation for building their reports. This highlights the growing importance of those standards as the number of companies that is relying on them to build their sustainability reports is constantly growing. On the other side of the standards spectrum, which is the assessment side, it is also shown that most companies have been getting or trying to get the ISO 14001 standard of environmental management systems in order to understand how to assess and evaluate their work. A smaller number of companies reported the use of the 50001 standards as well, which the energy management

systems standards, and most of these companies were from the automotive and engineering sectors.

In what regards the assessment tools, risk management is not only the most widely used tool, it is also by far the one that is most detailed inside each report. In fact, all twenty-five companies had entire sections to talk about their ways of dealing with all types of risks that might occur. Indeed, the most valid reason for this is that the company needs to be assessing and evaluating the possible risks that might occur, because otherwise there is a real threat that can hinder the company's activities and as a result can be a reason that causes massive economic or environmental losses. In this section, the companies detailed the risks and mentioned all types of risks that they have encountered and their ways of dealing with them. The other three assessment tools that were found in the reports were product life cycle assessment, supply chain management and input-output analysis. The two first methods were fairly used by the companies with them each being used by more than half of the companies. Although they were not detailed as much as the risk management tool, but most of the companies have acknowledged their importance and presence in their strategies. This explains that the companies are willing to focus on more than one technique to assess sustainability, however the focus is not evenly distributed. There is more focus on one technique over the others and the reason might be that the product life cycle assessment and the supply chain management techniques are not as urgent, as their absence does not highly affect their activities and performance in a negative way. This is one of the issues that were found by this study. In fact, it is only when there is something threatening on the short term that the companies are willing to invest all the time and energy to evaluate it. This suggests that the weaknesses of sustainability that were highlighted in previous sections still to a certain extent exist, as companies will always focus first and foremost on increasing their revenues and earns. The input-output technique was only highlighted by one engineering company as a method used to assess their scope 3 emissions. However, as input-output models are sometimes assumed to be a part of life cycle assessment analyses, other companies might have used this tool without explicitly stating it.

After disclosing the performance data, the standards and the assessment methods used, all companies presented their goals and targets for the future, which definitely include increasing productivity, but also always included decreasing the environmental impact. For this reason, each company presented its strategies and projects that they are willing to undertake in order to safeguard the continuity of their work and the environment they are working in. These strategies ranged from investing in renewable energy and enhancing energy efficient

production, to investing in recycling and carbon neutralising projects, to adopting more standards and promoting environmental programs.

In the end, we can say that the concept of sustainable development has definitely became a part of each company's strategic plan, as all companies that were studied had published detailed sustainability reports that contained a lot of information. Some of the information reported was very useful and concise, while some other was just brief and unclear. However, it is shown that companies are willing to invest and put the effort into promoting sustainability, which is an important and necessary decision that will insure the security of our environment and society. It is expected that the results of this research will provide several useful information for sustainability promoters and sustainability interested researchers. It definitely does not answer all the questions related to sustainability in firms but it can serve as a good starting point for more researches that would investigate the reasons of choosing a specific indicator, the number of sustainability assessment methods used or choosing a sustainability assessment method over the other and the basis of choosing and determining the future goals and strategies to meet them.

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