UNIVERSITÀ POLITECNICA DELLE MARCHE

FACOLTÀ DI ECONOMIA "GIORGIO FUÀ"

Corso di Laurea Magistrale in International Economic and Commerce

Sustainability and Environmental Impact in the Mobility Market: Comparing Conventional and Electric Means of Transportation

Relatore: Prof. Marco Giuliani

Tesi di Laurea di: Federico Bravi

Anno Accademico 2020 – 2021

ABSTRACT

The transport sector is one of the main contributors to various environmental burdens, but at the same time, the quality of life is strictly connected with the transport system, it has a vital role in society and economy. As a result, the need for greater fuel/energy efficiency in both conventional and electric means of transportation has become urgent.

In the first chapter, this thesis presents a general overview regarding the climate change, and then it focusses on sustainability, creating a complete picture of the current situation. In the second chapter the focus is placed on the environmental management system and its tools for monitoring and measuring environmental results. In the last chapter, this thesis presents a mix of the concepts described in the previous chapters, with the main difference that all of it is applied to transport sector.

TABLE OF CONTENTS

INTRODUCTION

Nowadays, public opinion is quite informed about the problem of climate change. It is known that climate change should not be underestimated, and certainly in the near future, it will bring profound changes in people's lifestyle. But despite this, it is still not clear what are the real consequences of this phenomenon, and what countermeasures should be taken in order to slow down the development of this global issue.

The aim of this thesis is to provide to the reader a general framework concerning the fundamental concepts of sustainable mobility, which are important to be known, because sustainability is increasingly at the heart of international policies. More specifically, we want to answer one question: are electric means of transportation more or less polluting than conventional ones? About this question, it important to point out that it is not correct to focus solely on the pollution related to the output of the means of transportation, but instead, we must consider the pollution related to the entire life cycle of the product. At the end of this thesis, will be considered pros and cons of the two different means of transportation, because it is not obvious that the electric one is greener than the conventional one.

The structure of the thesis is the following. In the first chapter, it is presented a general overview regarding the climate change issue, the concept of sustainability, and the global environmental policies. In the second chapter, it is analyzed the environmental management system, focusing on its two most relevant tools, which are the life cycle assessment approach and the environmental performance indicators. In the last chapter, it has been made a mix of the notions of the previous two chapters, applying these concepts and tools to the transport sector.

CHAPTER 1 – THE RELEVANCE OF SUSTAINABILITY IN THE ENVIRONMENTAL QUESTION: RELATION BETWEEN COMPANY AND ENVIRONMENT

1.1 CLIMATE CHANGE ISSUE

Over the last few decades the climate change issue has been increasingly at the heart of the discussions, nowadays it is possible to understand that this it is not a distant threat looming on the horizon[1], as it could be perceived few years ago, but it is already here. Climate change is affecting all regions of the world and the consequences are well known. The polar ice shields are melting and sea levels are rising, in some regions extreme weather events and rainfall are becoming more frequent while others are experiencing more extreme heat waves and droughts[2].

According to WWF, the main causes of climate change are mankind's increasing use of fossil fuels, deforestation, and increasingly intensive agriculture. Today's industrialized countries have built their economies on burning fuels for electricity

---

[1] United Nations Global Compact, United Nations Environment Programme (UNEP), Oxfam, and World Resources Institute (WRI) (2011), 'Adapting for a Green Economy: Companies, Communities and Climate Change', a Caring for Climate Report. Available at <https://www.unglobalcompact.org/library/116> accessed 3 October 2021.

[2] European Commission, 'Climate Change Consequences'. Available at <https://ec.europa.eu/clima/climate-change/climate-change-consequences_en> accessed 3 October 2021.

generation, transport and to develop industries[3], releasing huge amounts of carbon dioxide and methane into the atmosphere. It is clear that these problems will continue to worsen over the years unless countermeasures will be taken seriously.

Companies are one of the main actors regarding the production of pollution, especially those operating in the petrochemical sector. For this reason, the relationship between companies and the environment proves to be crucial for the balance of the ecosystem.

It is important to remind that the general surrounding environment is a sphere of resources, opportunities and constraints for the company, but at the same time, the latter with its operations turns out to be a factor of influence of the context of which it is part. The adoption of short-term speculative policies aimed at depleting natural resources well beyond the resilience of the surrounding environment, may then affect the companies themselves (Donato, 2000)[4].

A warming planet poses a variety of risks to businesses, from disrupted supply chains to rising insurance costs to labor challenges. Climate change and extreme weather events directly impact 70% of all economic sectors worldwide[5]. Global

---

[3] WWF, 'Causes of Climate Change'. Available at <https://www.wwf.org.nz/what_we_do/climateaction/causes_of_climate_change/> accessed 3 October 2021.

[4] Donato F. (2000), 'La Variante Ambientale nelle Politiche Ambientali: Sostenibilità Economica ed Ecologica', (*The Environmental Variant in Environmental Policies: Economic and Ecological Sustainability,* English translation, ed.), *Giuffrè Editore*.

[5] Forbes, 'Organizations Are Feeling The Pain Of Climate Change: Here are Five Ways It's Affecting Their Business'. Available at <https://www.forbes.com/sites/deloitte/2021/04/16/organizations-are-feeling-the-pain-of-climate-

warming will affect economic growth primarily through damage to property and infrastructure, loss of productivity, mass migration, and security threats. Global warming is expected to increase the frequency and severity of extreme weather events, sea level rise is also likely to affect economic performance as businesses are impacted and people suffer damage to their homes. While the initial economic response to repair this damage may be positive for GDP, the global economy faces an extreme challenge once it is recognized that such events are a permanent feature of the environment. At best, this could involve a short period of disruption as businesses relocate; at worst, it could be a permanent loss of capital stock and production. As the temperatures continue to rise, the damage will become increasingly permanent[6]. Considering that less capital stock will be available due to the damage inflicted from climate change, this will reflect later a fall in the productive capacity and therefore also in a reduction in outputs of the world economy. This reduction in output come also with an increase in the general price level as a result of global warming, this leads the world economy onto the possible inflationary effects. For example just think of agricultural yields, they are sensitive to weather conditions and as the climate becomes more extreme, more frequent droughts may reduce crop yields in areas where food production is fundamental. In

change-here-are-five-ways-its-affecting-their-business/?sh=579f31784e0c> accessed 3 October 2021.

[6] Wade K., and M. Jennings (2016), 'The Impact of Climate Change on the Global Economy', *Schroders*. Available at <https://www.schroders.com/de/SysGlobalAssets/digital/us/pdfs/the-impact-of-climate-change.pdf> accessed 3 October 2021.

this way, a ripple effect occurs, higher global food prices will reduce consumers' income in the process, so as the level of warming become even greater, food price inflation should rise. Higher energy costs are also presumably to boost inflation. As the climate becomes more extreme, muggy summer and harsh winter, energy demand will increase and supply could also shrink as the efficiency of existing power stations is compromised due to higher temperatures. Another problem is posed by the insurance industry, which recognizes that it is likely to bear much of the risk of global warming, and will be forced to raise the insurance costs to customers[7].

For these reasons, it is fundamental that companies play an active role to combat climate change, also to protect their businesses, adopting policies aimed to minimizing the environmental impact that productive activities have on the planet. In fact, with the passing of time, the concept of sustainable development has been more and more central for companies' policies.

---

[7] Wade K., and M. Jennings (2016), 'The Impact of Climate Change on the Global Economy', *Schroders*. Available at <https://www.schroders.com/de/SysGlobalAssets/digital/us/pdfs/the-impact-of-climate-change.pdf> accessed 3 October 2021.

1.2 SUSTAINABLE DEVELOPMENT

First of all, it is important to make clear that *sustainability* and *sustainable development* have different meanings. Sustainability refers to a long-term goal, while sustainable development refers to the many processes and pathways to achieve it[8].

Sustainable development was defined in the 1987 Brundtland Report 'Our Common Future', of the World Commission on Environment and Development as development that meets the needs of the present without compromising the ability of future generations to meet their own needs[9]. This definition established the need for integrated decision making capable of balancing the economic and social needs of people with the regenerative capacity of the natural environment. Sustainable development is a dynamic process of change in which the use of resources, the direction of investments, the orientation of technological development, and institutional change are made consistent with both future and present needs (Rogers, 2012)[10].

[8] Unesco, 'Sustainable Development'. Available at <https://en.unesco.org/themes/education-sustainable-development/what-is-esd/sd> accessed 5 October 2021.

[9] Brundtland G. (1987), 'Our Common Future-Call for Action'. Available at <https://www.cambridge.org/core/journals/environmental-conservation/article/abs/our-common-futurecall-for-action/65808D6676E07552EF891DF31C3DF7A1> accessed 5 October 2021.

[10] Rogers P. P., Jalal K. F., Boyd J. A. (2012), 'An Introduction to Sustainable Development', *Routledge.*

1.2.1 CORPORATE SUSTAINABILITY

Today, the concept of corporate sustainability is central to modern businesses, which are increasingly being pushed by governments and public opinion to develop their business in a more sustainable way. According to Marrewijk and Werre, there is no specific definition of corporate sustainability, and each company must develop its own definition that fits its purpose and goals[11].

A sustainable company will exist merely by recognizing environmental and social issues and incorporating them into its strategic planning[12]. This method of doing business is focused on the *triple bottom line* approach, which is based on the analysis and the balancing of three main pillars: environmental, social and economic.

As reported in the book of Sigurt Vitols and Norbert Kluge, it can be seen that there are six key elements for a sustainable company, which are:

- a multi-dimensional concept of sustainability and stakeholder value is the central guiding principle of the sustainable enterprise;
- in line with this guiding principle, the sustainable enterprise has a set of sustainability goals and a detailed strategy to achieve them;

---

[11] Marrewijk M. V., Werre M. (2003), 'Multiple levels of Corporate Sustainability', Journal of Business Ethic. Available at <https://doi.org/10.1023/A:1023383229086> accessed 5 October 2021.

[12] Aras G., Crowther D. (2008), 'Governance and sustainability: An investigation into the relationship between corporate governance and corporate sustainability'. Available at <https://doi.org/10.1108/00251740810863870> accessed 5 October 2021.

- stakeholders, in particular employees, are involved in the decision making process of the sustainable enterprise;
- the sustainable enterprise has an externally verifiable reporting system for both financial and nonfinancial (environmental, social, etc.) performance that allows progress toward sustainability goals to be measured;
- incentives within the sustainable enterprise are designed to support sustainability. A key role is played here by trying a portion of executive remuneration the achievement of sustainability goals;
- the company's ownership base is dominated by long-term responsible investors concerned not only with financial return but also with the social environment impacts of their investments[13].

Considering how fundamental corporate sustainability is for businesses, it is interesting to know that, according to Forbes, 90% of executives think sustainability is important, only 60% of companies have a sustainability strategy. Often, companies that speak of being sustainable are lacking when it comes to implementation[14] and sometimes they do not know how to integrate sustainability issues into their business routines and their strategies. But the main problem is due

[13] Vitols S. and N. Kluge (2011), 'The Sustainable Company: A New Approach to Corporate Governance'. Available at <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.470.3563&rep=rep1&type=pdf> accessed 6 October 2021.

[14] Forbes, 'Why Corporate Strategies Should Be Focused On Sustainability'. Available at <https://www.forbes.com/sites/forbesbusinesscouncil/2021/02/10/why-corporate-strategies-should-be-focused-on-sustainability/?sh=ce632b87e9f2> accessed 24 October 2021.

to the fact that companies don't truly understand the benefits of being sustainable on their business, they only see sustainability as an extra cost to their budget. In fact it is the opposite, a sustainable business strategy aims to positively impact environment or society, or even both. But that's not all, these strategies contribute to organization's overall success, spending more money on sustainable business practices can boost a company's profitability, studies show that the most sustainable companies are also the most profitable[15].

According to Natalie Chladek, there are several benefits of being sustainable in business:

- protect your brand and mitigate risks. Improper practices damage a company's reputation and cost it customers. Plus, dealing with a public relations disaster can divert valuable human and financial resources from the core business;
- being purpose-driven is a competitive advantage. Infusing a company with purpose can help to attract a motived, skilled workforce that drives financial success. Making a company an organization that does good in the world, rather than just a place that provides paycheck, can be a competitive advantage when attracting the best talent;

[15] Harvard Business School Online, 'Why You Need Sustainability In Your Business Strategy'. Available at <https://online.hbs.edu/blog/post/business-sustainability-strategies> accessed 24 October 2021.

- there is a growing market for sustainable goods. Millennials are more willing to pay more for products that contain sustainable ingredients, or for products that have social responsibility claims. In this way, it is possible to gain market share by converting sustainability-minded customers and increasing sales;
- cooperative action can drive change. Purpose-driven organizations that work together to address these issues have experienced great success[16].

To pursue efficient sustainable strategies, companies must have the support of governments and civil society which together determine how markets operate, this is the only way this can be possible. Governments at various levels make public policies that include plans for laws and all kinds of actions and services. Strategies by government, businesses or charities are more practical than policies and they consider the capacities and comparative weaknesses and strengths of the stakeholders. However, strategies do not describe in detail what to do and how to achieve the goals, but only provide the general outline for a certain course of action[17].

[16] Harvard Business School Online, 'Why You Need Sustainability In Your Business Strategy'. Available at <https://online.hbs.edu/blog/post/business-sustainability-strategies> accessed 24 October 2021.

[17] Neefjes K. (2000), 'Environments and Livelihoods: Strategies for Sustainability'. Available at <https://policy-practice.oxfam.org/resources/environments-and-livelihoods-strategies-for-sustainability-122750/> accessed 26 October 2021.

1.2.2 TRIPLE BOTTOM LINE (TBL)

Those who adhere to this new sustainable economic model, also adhere to focusing not only on profits, but also on the well-being of the environment and the community. A company that acts according to the TBL seeks to preserve the natural environment, limit its impact or at least not to damage[18]. TBL and its core value of sustainability have become compelling in the business world due to accumulating anecdotal evidence of greater long-term profitability[19].

As mentioned in the previous paragraph, there are three main pillars and the most discussed one is about environmental sustainability. According to Goodland, environmental sustainability seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans (Goodland, 1995)[20]. An important contribution to the concept of environmental sustainability was made by the OECD Environmental Strategy for the first decade of the 21st

[18] Zak A. (2015), 'Triple Bottom Line Concept in Theory and Practice'. Available at <https://www.researchgate.net/profile/Agnieszka-Zak-2/publication/281703207_Triple_bottom_line_concept_in_theory_and_practice/links/5f081c5392851c52d626999e/Triple-bottom-line-concept-in-theory-and-practice.pdf> accessed 10 October 2021.

[19] Slaper T. F., Hall T. J. (2013), 'The Triple Bottom Line: What Is It and How Does It Work?'. Available at <http://www.ibrc.indiana.edu/ibr/2011/spring/article2.html> accessed 26 October 2021.

[20] Goodland R. (1995), 'The Concept of Environmental Sustainability'. Available at <https://doi.org/10.1146/annurev.es.26.110195.000245> accessed 10 October 2021.

Century (OECD, 2001)[21]. The strategy defines four specific criteria for environmental sustainability: regeneration (renewable resources should be used efficiently and their use should not exceed their long-term rates of natural regeneration), substitutability (non-renewable resources should be used efficiently and their use should be limited to a level that can be offset by substitution with renewable resources or other forms of capital), assimilation (the release of hazardous or polluting substances into the environment should not exceed their assimilative capacity), and avoidance of irreversibility (Moldan, 2012)[22].

To enforce this pillar, companies are focusing on reducing their carbon footprints packaging waste, water usage and their overall effect on the environment. Companies have found that a positive impact on the planet can also have a positive financial impact. For example, when less material is used for packaging, overall spending on those materials usually decreases as well. According to Hoffman, it is also possible to understand the importance of the strategic timing of when a company should begin implementing sustainable environmental policies. In fact, some of the companies studied in his book acknowledge the dangers of starting too

---

[21] OECD (2001), 'OECD Environmental Strategy for the First Decade of the 21st Century'. Available at <https://www.oecd.org/env/indicators-modelling-outlooks/1863539.pdf> accessed 10 October 2021.

[22] Moldan B., S. Janoušková, T. Hák (2012), 'How to understand and measure environmental sustainability: Indicators and targets'. Available at <https://www.sciencedirect.com/science/article/pii/S1470160X11001282> accessed 10 October 2021.

early on climate action, while others highlights the risks of starting too late (Hoffman, 2007)[23].

Social sustainability is another pillar of the triple bottom line approach, that is important for wellness of the company and not just that. This pillar refers to the implementation of beneficial and fair business practices for the workforce, human capital, community, and governments, not just the stakeholders with whom the company has direct, transactional relationships (such as employees, suppliers and customers). A company creates a social structure in which the well-being of the company, labor, and the interests of shareholders are interdependent[24].

The idea behind it is paid to the fact that these practices provide value to the society and "give something back" to the community, for example fair wages and the provision of health care coverage. Aside from the moral aspect of being "good" for society, disregarding social responsibility can affect the company's performance and the sustainability of the business (Willianms, 2015)[25].

---

[23] Hoffman A. J. (2007), 'Carbon Strategies: How Leading Companies Are Reducing Their Climate Change Footprint', *University of Michigan Press.*

[24] Zak A. (2015), 'Triple Bottom Line Concept in Theory and Practice'. Available at <https://www.researchgate.net/profile/Agnieszka-Zak-2/publication/281703207_Triple_bottom_line_concept_in_theory_and_practice/links/5f081c5392851c52d626999e/Triple-bottom-line-concept-in-theory-and-practice.pdf> accessed 10 October 2021.

[25] Willianms, E. et al (2015), 'Business and Management Studies', Redfame Publishing, United States, Vol. 1, No. 2. Available at <https://www.academia.edu/15336658/Business_and_Management_Studies_Vol_1_No_2_September_2015> accessed 13 October 2021.

The economic pillar of sustainability is where most businesses believe they are on solid ground. In a capitalist economy, a company's success depends primarily on its financial performance, or the profit it generates for shareholders. Strategic planning initiatives and major business decisions are usually carefully designed to maximize profits while reducing costs and mitigating risk. In the past, this exhausted the goals of many companies. Now, purposeful leaders are discovering that they have the power to leverage their businesses to effect positive change in the world without hampering financial performance. In many cases, implementing sustainability initiatives has proven to drive business success[26].

It is important to clarify that the TBL approach cannot be interpreted as traditional business accounting increased by the social and environmental impact. The profit generated should be consistent with the other two elements. The TBL approach allows the community to participate, it shows that a company does not only for profit, but also for the members of this community[27].

The triple bottom line approach is not free of critics, there are several aspects that puzzles a lot of experts. TBL is a difficult concept for many organizations because

---

[26] Miller K. (2020), 'The Triple Bottom Line: What It Is & Why It's Important', *Harvard Business School Online*. Available at <https://online.hbs.edu/blog/post/what-is-the-triple-bottom-line> accessed 10 October 2021.

[27] Zak A. (2015), 'Triple Bottom Line Concept in Theory and Practice'. Available at <https://www.researchgate.net/profile/Agnieszka-Zak-2/publication/281703207_Triple_bottom_line_concept_in_theory_and_practice/links/5f081c5392851c52d626999e/Triple-bottom-line-concept-in-theory-and-practice.pdf> accessed 10 October 2021.

it implies that a company's responsibilities extend much further than just the economic aspects of producing products and providing services that customers want, to regulatory standards, at a profit[28].

According to Elkington, the three components can and need to be measured (Elkington, 1997)[29]. The first problem with the TBL approach, is that there is no a common unit of measurement, so it is difficult to compare the different outputs of the three pillars. According to Tullberg, the incommensurability argument states that there is no way to compare, for example, changes in carbon dioxide emissions with changes in water pollution, or a change in the proportion of women in the workforce with a change in working conditions[30]. In addition, according to Hubbard, social and environmental performance is unique to each corporation, or at least industry, and is difficult to quantify[31], therefore there is no standard method that can be used for every company.

Another challenge regards the environmental cost-benefit analysis (CBA), which refers to the economic evaluation of policies and projects that have the deliberate

---

[28] Zak A. (2015), 'Triple Bottom Line Concept in Theory and Practice'. Available at <https://www.researchgate.net/profile/Agnieszka-Zak-2/publication/281703207_Triple_bottom_line_concept_in_theory_and_practice/links/5f081c5392851c52d626999e/Triple-bottom-line-concept-in-theory-and-practice.pdf> accessed 10 October 2021.

[29] Elkington J. (1997), 'Cannibals With Forks: The Triple Bottom Line of 21st Century Business', *Capstone Publishing Ltd, Oxford.*

[30] Tullberg J. (2012), ' Triple bottom line – a vaulting ambition?', Business Ethics: *A European Review.* Available at <https://doi.org/10.1111/j.1467-8608.2012.01656.x> accessed 12 October 2021.

[31] Hubbard G. (2006), ' Measuring Organizational Performance: Beyond The Triple Bottom Line'. Available at <https://doi.org/10.1002/bse.564> accessed 13 October 2021.

goal of improving the provision of environmental services or actions that might affect the environment as an indirect consequence[32]. Business' impacts are often not fully costed, meaning that there are externalities that aren't being captured. The total costs of wastewater, carbon dioxide, land reclamation and waste in general are not easy to calculate because companies are not always the ones on the hook for waste they produce.

The biggest challenge for today's businesses is about how to integrate environmental, social and financial impacts into daily management decision-making process, considering that there are various tensions between these goals. While these initiatives can benefit one another in the long-term, they are often conflicting in their need of resources[33]. Managers must balance these multiple goals when allocating resources, which is difficult because the long-term financial gains of social/environmental initiatives may not fit well into a traditional capital budgeting format, unless the risks and reputation-related impacts are measured and integrated into the decisions[34]. Tensions continue to develop as business unit and

[32] Atkinson G., Mourato S. (2008), 'Environmental Cost-Benefit Analysis'. Available at <https://doi.org/10.1146/annurev.environ.33.020107.112927> accessed 18 October 2021.

[33] Margolis, J.D., J.P. Walsh (2003), 'Misery loves company: rethinking social initiatives by business'. Available at <https://www.jstor.org/stable/3556659> accessed 18 October 2021.

[34] Epstein J.M., A.R. Buhovac, K. Yuthas (2015), 'Managing Social, Environmental and Financial Performance Simultaneously'. Available at <https://www.sciencedirect.com/science/article/pii/S0024630112000726> accessed 18 October 2021.

facility leaders are under pressure to increase short-term earnings (Thompson, 2007)[35].

1.3 GLOBAL ENVIRONMENTAL POLICIES

To better understand all the concepts that are behind sustainable strategies and policies, it is important to have an overview about the most important agreements made by governments, considering the fact that they have a fundamental role for the success of sustainable development. Over the years, there have been many initiatives, but in this thesis will be analyzed the latest initiatives which produced the strongest impact in the actual economy.

A crucial moment for the international community was made in 1972 with the Stockholm Conference. It was the first world conference to make the environment a major issue. The participants adopted a series of principles for sound management of the environment including the *Stockholm Declaration and Action Plan for the Human Environment* and several resolutions[36].

The Stockholm Declaration, placed environmental issues at the forefront of international concerns and market the start of a dialogue between industrialized and developing countries on the link between economic growth, the pollution of the air,

[35] Thompson Jr., L.M. (2007), 'Why 'short termism' may be short lived'.

[36] United Nations, 'United Nations Conference on the Human Environment, 5-16 June 1972, Stockholm'. Available at <https://www.un.org/en/conferences/environment/stockholm1972> accessed 30 October 2021.

water, and oceans and the well-being of people around the world. The Action Plan contained three main categories: Global Environment Programme, Environmental management activities and at least International measures to support assessment and management activities carried out at the national and international levels. In addition, these categories were broken down into 109 recommendations[37].

In the Stockholm Declaration, the concept of sustainable development emerged, and after that, there have been the creation of important treaties. This declaration led to the creation of the World Commission on Environment and Development (WCED, 1983), namely Brundtland Commission. The mission of Brundtland Commission was about unite countries to pursue sustainable development together. In 1987, the commission published "Our Common Future" in the Brundtland report. The Brundtland report represents a fundamental act for the introduction of the concept of sustainability in the legislative frameworks. Indeed, starting from this document a continuous process has been set up for the consideration of the sustainability as fundamental paradigm of action (Lafratta, 2004)[38].

A further step in the process for the achievement of sustainable development refers to the identification of the Millenium Development Goals (MDG). These objectives have been defined in the year 2000 and they define a complex series of targets

[37] United Nations, 'United Nations Conference on the Human Environment, 5-16 June 1972, Stockholm'. Available at <https://www.un.org/en/conferences/environment/stockholm1972> accessed 30 October 2021.

[38] Lafratta P. (2004), 'Strumenti Innovativi per lo Sviluppo Sostenibile', (*Innovative Tools for Sustainable Development,* English translation, ed.), *FrancoAngeli.*

(Mondini, 2019)[39]. They are contained in the Millennium Declaration and unanimously adopted by 189 nations. The declaration contains eight specific MDGs. The main aim of the MDGs is to eradicate extreme poverty around the world by 2015. As such, the MDGs are the most ambitious and most broadly supported development goals the world has ever established (Stijn, 2007)[40].

The Millennium Development Goals were the foundation of the Sustainable Development Goals (SDGs), which born at the United Nation Conference on Sustainable Development in Rio 2012. The legacy and achievements of the MDGs provide a valuable lesson and experience to begin work on the new goals. The SDGs are a bold commitment to finish what was started, and tackle some of the more pressing challenges facing the world today[41]. The SDGs were adopted in 2015 by 193 Member States and are contained in the 2030 Agenda for Sustainable Development. The Agenda consists of 17 SDGs, the goals are made tangible by targets which are 169, ranging from 5 to 12 targets per goal[42]. Each goal has specific targets to be achieved, which the most important are about wipe out poverty, fight

---

[39] Mondini G. (2019), 'Sustainability Assessment: from Brundtland Report to Sustainable Development Goals'. Available at <https://siev.org/wp-content/uploads/2020/02/23_15-_-MONDINI_eng.pdf> accessed 3 November 2021.

[40] Stijn C., E. Feijen (2007), 'Financial Sector Development and the Millennium Development Goals', *The World Bank*.

[41] Oslo Government Centre, 'Sustainable Development Goals'. Available at <https://www1.undp.org/content/oslo-governance-centre/en/home/sustainable-development-goals/background.html> accessed 5 November 2021.

[42] Hák T., Janoušková S., Moldan B (2016) 'Sustainable Development Goals: A need for relevant indicators'. Available at <https://doi.org/10.1016/j.ecolind.2015.08.003> accessed 5 November 2021.

inequality and tackle climate change over the next 15 year[43]. The SDGs can be broadly divided into three categories: First, an extension of MDGs that includes the first seven SDGs; second group is inclusiveness (jobs, infrastructure, industrialization, and distribution). It includes goals 8, 9, and 10; and the third group is on sustainability and urbanization that covers the last seven goals: sustainable cities and communities, life below water "consumption and production; climate action; resources and environment; peace and justice; and the means of implementation and global partnership for it"[44].

The SDGs have to face four major challenges. The first one concerns the huge costs of the SDGs. Another one regards maintaining peace, which is essential for development. A threat to international peace and stability by nonstate actors is emerging as a major factor for both developed and developing countries. The third issue is about the measuring process, because a number of targets in the SDGs are not quantified. Measurability will depend on the availability of data and capacity to measure them. The last challenge regards accountability. There was a lack of

[43] Cf, O. D. D. S. (2015), 'Transforming our world: the 2030 Agenda for Sustainable Development'. *United Nations: New York, NY, USA.*

[44] Kumar S, Kumar N, Vivekadhish S. (2016), 'Millennium Development Goals (MDGS) to Sustainable Development Goals (SDGS): Addressing Unfinished Agenda and Strengthening Sustainable Development and Partnership'. Available at <https://www.ijcm.org.in/text.asp?2016/41/1/1/170955> accessed 5 November 2021.

accountability for inputs into MDGs at all levels. This challenge needs to be addressed in SDGs[45].

The SDGs coincided with another historic agreement reached in 2015 at the COP21 Paris Climate Conference. Together with the Sendai Framework for Disaster Risk Reduction, signed in Japan in March 2015, these agreements provide a set of common standards and achievable targets to reduce carbon emissions, manage the risks of climate change and natural disasters, and to build back better after a crisis[46]. Focusing on the connection between the 2030 Agenda and the Paris Agreement, it is possible to understand that there is a strong correlation between the SDGs and the NDCs (Nationally Determined Contributions), which are the heart of the Paris Agreement. The NDCs embody efforts by each country to reduce national emissions and adapt to the impacts of climate change. The Paris Agreement requires each Party to prepare, communicate and maintain successive nationally determined contributions that it intends to achieve. Parties shall purse mitigation measures, with the aim of achieving the objectives of such contributions. In short, the Paris

[45] Kumar S, Kumar N, Vivekadhish S. (2016), 'Millennium Development Goals (MDGS) to Sustainable Development Goals (SDGS): Addressing Unfinished Agenda and Strengthening Sustainable Development and Partnership'. Available at <https://www.ijcm.org.in/text.asp?2016/41/1/1/170955> accessed 5 November 2021.

[46] Oslo Government Centre, 'Sustainable Development Goals'. Available at <https://www1.undp.org/content/oslo-governance-centre/en/home/sustainable-development-goals/background.html> accessed 5 November 2021.

Agreement requests each country to outline and communicate their post-2020 climate actions, known as their NDCs[47].

These two implementation processes are kept separate, despite the many existing thematic overlaps and the shared objective of achieving global SD, but the climate activities in the NDCs can support the achievement of a multitude of SDGs and their targets. Numerous NDC climate activities entail synergies that can promote several SDGs at once. To generate co-benefits, NDC and SDG implementation process should be coordinated to prevent duplication and thereby reduce the costs and to achieve a more systematic implementation of the 2030 Agenda at country level[48].

The current state of the climate change issue is very complex, NDCs are critical tools, they have the primary means for governments to indicate to the international community the specific steps countries will take to tackle climate change. The SDGs are universally adopted goals that provide a shared blueprint for a sustainable future. The strongest links between NDCs and the SDGs are found in the areas of

---

47 United Nations Climate Change, 'Nationally Determined Contributions (NDCs)'. Available at <https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/nationally-determined-contributions-ndcs> accessed 5 November 2021.

48 Brandi C., A. Dzebo, H. Janetschek (2017), 'The case for connecting the implementation of the Paris Climate Agreement and the 2030 Agenda for Sustainable Development'. Available at <https://www.econstor.eu/handle/10419/199809> accessed 5 November 2021.

land use, food, energy and water. By contrast, many SDGs are highly under-represented in NDC activities[49].

At the national level there is growing complexity in sustainability and climate policymaking and action, where possible conflicts and synergies abound among multiplicity of actors regarding various goals[50]. Evidence of effective orchestration between NDCs and SDGs is largely absent at national level, where the implementation responsibilities for both chiefly lie[51].

Regarding individual states, it is also interesting to figure it out that governments have several policy instruments in order to achieve some degree of sustainable development:

- regulation, for example through laws and bylaws that forbid certain chemicals to be used, and set environmental standards and maximum limits for pollution;

[49] Dzebo A., Janetschek H., Brandi C., Iacobuta G. (2019), 'Connections between the Paris Agreement and the 2030 Agenda'. Available at <https://www.sei.org/wp-content/uploads/2019/08/connections-between-the-paris-agreement-and-the-2030-agenda.pdf> accessed 6 November 2021.

[50] Persson A., H. Runhaar (2018), 'Conclusion: Drawing Lessons for Environmental Policy Integration and Prospects for Future Research'. Available at <https://www.researchgate.net/profile/Hens-Runhaar/publication/326101247_Conclusion_Drawing_lessons_for_Environmental_Policy_Integration_and_prospects_for_future_research/links/5e07900392851c8364a28cbd/Conclusion-Drawing-lessons-for-Environmental-Policy-Integration-and-prospects-for-future-research.pdf> accessed 8 November 2021.

[51] Keohane R. O., D. G. Victor (2016), 'Cooperation and Discord in Global Climate Policy'. Available at <https://depts.washington.edu/envirpol/wp-content/uploads/2016/04/coll_Victor_paper.pdf> accessed 8 November 2021.

- market-based instruments, in particular taxation and subsidization. These can include subsidies for the development of environmental-benign technologies such as sustainable agriculture, tariffs to limit the importation and use of particular chemicals, and taxes on pollution, deforestation, mining and other environmental externalities. Tariffs and resource-taxes thus act as disincentives: they discourage what is unwanted, and they provide a signal to markets to develop alternatives, in particular when they become the main source of revenue for government;
- public campaigns, that help to create awareness among citizens and enterprises of the environmental impacts of their behavior;
- governments can invest themselves, for example in the regeneration of mangrove forests, the clean-up of polluted waters and land, infrastructure to protect human settlements from landslides, or the protection of steep mountain slopes;
- many governments consider making claims through invoking the principle that the polluter pays in cases of industrial contamination, even when the pollution took place at a time when no anti-pollution laws existed, or when standards were different[52].

[52] Neefjes K. (2000), 'Environments and Livelihoods: Strategies for Sustainability'. Available at <https://policy-practice.oxfam.org/resources/environments-and-livelihoods-strategies-for-sustainability-122750/> accessed 26 October 2021.

CHAPTER 2 – TOOLS AND METHODOLOGIES FOR MEASURING AND MONITORING ENVIRONMENTAL RESULTS

2.1 ENVIRONMENTAL MANAGEMENT SYSTEM (EMS)

In order to better understand the methods and tools for the control of environmental results, must be first mentioned the importance of the *environmental management system (EMS)* and its relevance in the actual economic system.

Environmental management systems can be defined as operational mechanisms, in terms of both tools and rule for the monitoring and the commercial policy of the company for the environmental aspects (Donato, 2000)[53]. Underpinning the active environmental management approach, there is the concept of "continuous improvement" which acknowledges that issues can always occur, but also that a responsible organization learns from its mistakes and try to create the conditions under which similar errors do not occur again in the future (Gervasoni, 2007)[54].

Environmental management systems have emerged as a means to systematically apply business management to environmental issues to enhance a firm's long-run

[53] Donato F. (2000), 'La Variante Ambientale nelle Politiche Ambientali: Sostenibilità Economica ed Ecologica', (*The Environmental Variant in Environmental Policies: Economic and Ecological Sustainability,* English translation, ed.), *Giuffrè Editore.*

[54] Gervasoni S. (2007), 'Sistemi di Gestione Ambientale' (*Environmental Management Systems,* English translation, ed.), *Hoepli.*

financial performance by developing processes and products that simultaneously improve competitive and environmental performance (Stead, 1992)[55]. EMS provides order and coherence for organizations for dealing with environmental problems through the allocation of resources, the attribution of responsibilities and continuous evaluation and systematic of practice, procedures and processes. An organization develops an EMS with the main and ultimate objective of continually improve their environmental performance through a systematic mechanism (Gervasoni, 2007)[56]. This type of mechanism is the Plan-Do-Check-Act (PDCA) cycle, which ensures that environmental issues are systematically identified, controlled and monitored, in accordance with an organization's environmental policy, which is regularly reviewed and updated. PDCA has been practiced as a main competitive advantage and continuous problem solving approach by many successful companies all over the world[57].

The EMS uses this model which incorporates several steps. The first step is to *Plan* (Planning), that is a fundamental part of this process and consists of few actions. In this phase improvements opportunities are identified, and later priorities are assigned to them. Likewise, the current situation of the process to be analyzed is

---

[55] Stead W. E., Stead J. G. (1992), 'Management for a Small Planet: Strategic Decision Making and the Environment', *Sage Publications.*

[56] Gervasoni S. (2007), 'Sistemi di Gestione Ambientale' (*Environmental Management Systems,* English translation, ed.), *Hoepli.*

[57] Gidey E., Beshah B. (2014), 'The Plan-Do-Check-Act Cycle of Value Addition. Available at <http://dx.doi.org/10.4172/2169-0316.1000124> accessed 6 November 2021.

defined by means of consistent data, the problem causes are determined, and possible solutions are proposed to solve it.

The *Do* phase is intended to implement the action plan, select and document the information. Also, unexpected events, learned lessons and the acquired knowledge must be considered.

The third phase is about *Check*. In this step, the results of the actions implemented in the before step are analyzed. A before-and-after comparison is performed verifying whether there were improvements and if the stablished objectives were achieved.

The last phase is *Act*, which consists in developing methods aimed to standardize the improvements (in the case objectives had been reached). In addition, the proof is repeated to obtain new data and re-test the improvement (only if data are insufficient or circumstances had changed), or the project is abandoned and a new one is begun from the first stage (in the case the implemented actions did not yield effective improvements)[58].

EMS and also PDCA cycle are promoted by the International Organization for Standardization (ISO[59]). This organization provides thousands of international

---

[58] Realyvásquez-Vargas A, Arredondo-Soto KC, Carrillo-Gutiérrez T, Ravelo G. (2018), ‘Applying the Plan-Do-Check-Act (PDCA) Cycle to Reduce the Defects in the Manufacturing Industry. A Case Study’. Available at <https://doi.org/10.3390/app8112181> accessed 13 November 2021.

[59] ISO is an independent, non-governmental international organization with a membership of 165 national standards bodies. Through its members, it brings together experts to share knowledge and develop voluntary, consensus-based, market relevant International Standards that support innovation

standards, but the one that is interesting to focus on, also considering the previous considerations regards the PDCA cycle, is the ISO 14001. Formally adopted in 1996 by the ISO, it was one of the first international environmental management standards. ISO 14001 was designed to help firms identify and control the environmental impact of their activities, products, or services and to help stakeholders recognize firms committed to improving their environmental impact[60]. This standard specifies the requirements for an environmental management system that an organization can use to enhance its environmental performance. ISO 14001 helps an organization achieve the intended outcomes of its environmental management system, which provide value for the environment, the organization itself and interested parties. This standard does not state specific environmental performance criteria and it can be used in whole or in part to systematically improve environmental management[61].

ISO 14001 can be used to aspire to a certification, a self-declaration, or just as a guideline in order to improve the EMS. The main advantages of getting the

and provide solutions to global challenges. Available at <https://www.iso.org/about-us.html> accessed 14 November 2021.

[60] Delmas M. A., Montes-Sancho M. (2011), 'An Institutional Perspective on the Diffusion of International Management System Standards: The Case of the Environmental Management Standard ISO 14001', *Business Ethics Quarterly*. Available at <https://www.cambridge.org/core/journals/business-ethics-quarterly/article/abs/an-institutional-perspective-on-the-diffusion-of-international-management-system-standards-the-case-of-the-environmental-management-standard-iso-14001/5F232210367B7919498C501900970004> accessed 14 November 2021.

[61] ISO, 'ISO 14001:2015'. Available at <https://www.iso.org/standard/60857.html> accessed 15 November 2021.

certification deal with marketing purposes, people prefer to relate with organizations that are environmentally-friendly, and nowadays a lot of organizations collaborate only with other companies that has a ISO 14001 certification, for this reason, not having it could be a major disadvantage. Considering that it is a certifiable standard, it is possible to obtain by an accredited certification body, a certificate of conformity of the standard's requirements. This type of certification doesn't attest that the organization has a particular environmental performance or a low environmental impact. Instead it demonstrate that the company has an appropriate management system to monitor environmental impact of its activities, and constantly looking for its own improvement in a sustainable and coherent way, so it is easy to understand that this not a product certification, instead it is a process certification. Claims of conformity to ISO 14001 are not acceptable unless all its requirements are incorporated into an organization's environmental management system and fulfilled without exclusion[62].

There are different tools and methodologies for measuring and monitoring environmental performance within environmental management systems. The most commonly used refer to *life cycle assessment (LCA)* and *environmental performance indicators (EPIs)* (Donato, 2000)[63].

---

[62] ISO, 'ISO 14001:2015'. Available at <https://www.iso.org/standard/60857.html> accessed 15 November 2021.

[63] Donato F. (2000), 'La Variante Ambientale nelle Politiche Ambientali: Sostenibilità Economica ed Ecologica', (*The Environmental Variant in Environmental Policies: Economic and Ecological Sustainability,* English translation, ed.), *Giuffrè Editore.*

2.2 LIFE CYCLE ASSESSMENT (LCA)

Life cycle assessment has seen a strong development in both methodology and applications since the first life-cycle-oriented methods were proposed in the 1960s. LCA can be defined as inventory and systematic assessment of environmental effects regarding a specific product and any by-products for all stages of their lives in a given context. The LCA stands as a relevant methodology view to obtaining a proper environmental balance of the product from "cradle to grave" (Donato, 2000)[64]. In fact, the objects studied in LCA are frequently physical products and the term "product system" indicates that a life cycle perspective is taken, which means that all processes required to provide the product's function are considered. The principal reason for taking a life cycle perspective is that it enables the identification and prevention of burden shifting between life cycle phases or processes that occurs when efforts to reduce environmental impacts in one process or life cycle phase inadvertently lead to (potentially greater) environmental impacts in other processes or life cycle phases (Hauschild, 2018)[65].

A formal standardization process was initiated under the auspices of the International Organization of Standardization to develop a global standard for LCA. The standard development resulted in the adoption and release of four standards,

---

[64] Donato F. (2000), 'La Variante Ambientale nelle Politiche Ambientali: Sostenibilità Economica ed Ecologica', (*The Environmental Variant in Environmental Policies: Economic and Ecological Sustainability,* English translation, ed.), *Giuffrè Editore.*

[65] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer*.

addressing the principles and framework (ISO 14040), the goal and scope definition (ISO 14041), the life cycle impact assessment LCIA (ISO 14042) and the life cycle interpretation LCI (ISO 14043). In 2006 revision, the latter three were compiled in the ISO 14044 standard detailing the requirements and guidelines, without changing any requirements in the standards (Hauschild, 2018)[66]. LCA standards ISO 14040 and 14044 belong to the ISO 14000 family, which cover various aspects of environmental management[67].

The application areas of LCA are numerous. Primarily, a distinction can be made between public and private application. Public LCA studies are used to support the development of environmental legislation and regulation, development of criteria for environmental taxes, standards, or eco-labelling programmes, or to provide consumer information. In the private sector, companies may use the results of the LCA study to support product development or marketing, to increase the credibility of the company's environmental policy, or to guide suppliers to act in an environmentally friendly behavior[68]. Besides that, the ISO standard differentiates the methodological framework of LCA from its various applications, which are

---

[66] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*

[67] Hunkeler D. (2016), 'Life Cycle Assessment (LCA): A Guide to Best Practice'. Available at <https://doi.org/10.1007/s11367-016-1083-z> accessed 23 November 2021.

[68] Miettinen P., Hämäläinen R. P. (1997), 'How to benefit from decision analysis in environmental life cycle assessment (LCA)'. Available at <https://doi.org/10.1016/S0377-2217(97)00109-4> accessed 25 November 2021.

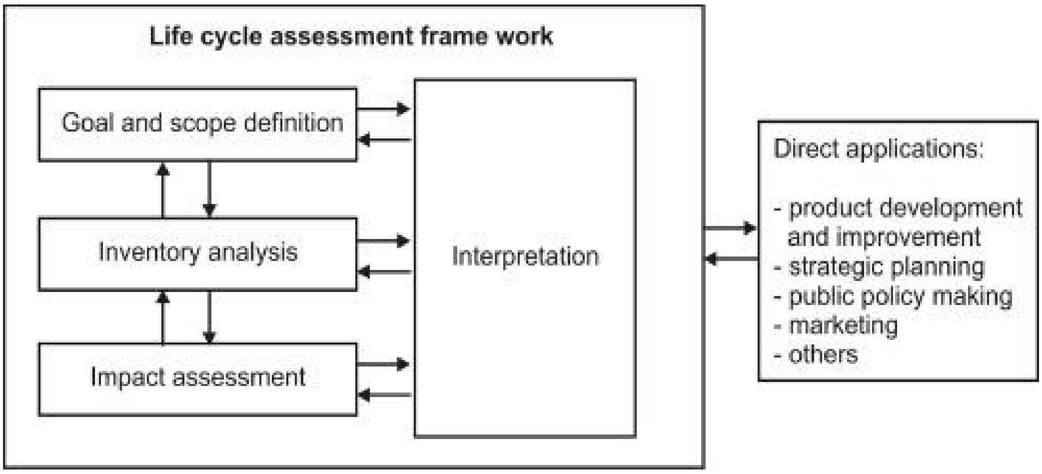
diverse, such as product development, Ecolabelling, carbon footprint and other footprints (Hauschild, 2018)[69].

A life cycle assessment study comprises four steps:

- goal and scope aims to define how large the product life cycle portion of the assessment should be and what purpose the assessment serves. The criteria that serve the system comparison and the specific times are described in this step;
- the inventory analysis describes the material and energy flows within the product system and especially the interaction with the environment. All the fundamental processes, subsidiary energy and material flows are described later;
- the details from the inventory analysis are used for impact assessment. The indicator results of all impact categories are detailed in this phase; the importance of each impact category is assessed by normalization and possibly also by weighting;
- the interpretation of a life cycle includes a critical review, the determination of data sensitivity and also the result presentation (Murali Krishna, 2017)[70].

[69] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer*.
[70] Murali Krishna I. V., Manickam V. (2017), 'Environmental Management: Science and Engineering for Industry', *Elsevier*.

Figure 1. The Four Stages under the ISO 14040 guidelines



Source: Murali Krishna I. V., Manickam V. (2017), 'Environmental Management: Science and Engineering for Industry', Elsevier.

The first step of LCA's methodology concerns goal definition and scoping, that is the planning phase of LCA. The goal definition provides the context of the LCA study and forms the basis for defining the scope in which the assessment is framed and outlined in accordance with the goal definition, mainly in terms of:

- functional unit definition: a quantitative description of the function or service for which the assessment is being conducted, and the basis for determining the reference product flow that scales the data collection in the next LCA phase, the inventory analysis;
- scoping the product system, deciding which activities and processes are part of the life cycle of the product under study;

- selection of the assessment parameters, which means the impacts that shall be assessed in the study;
- selection of the geographical and temporal boundaries and framework of the study, as well as the technology level relevant to for the processes in the product system;
- decide which perspective apply in the study: should it be a follow-up study assessing the effects expected as a consequence of choosing one alternative over another, or should it be an attributional study assessing the effects associated with the activity under study?;
- identify the need of perform critical review, especially if it is a comparative study that will be made available to the public.

The goal definition and the ensuring scope definition are fundamental in the interpretation of the study results because these definitions involve decisions that determine the collection of data and the way the system is modelled and evaluated. Therefore, they have a strong influence on the validity of the conclusions and recommendations based on the results of the LCA (Hauschild, 2018)[71].

Following the definition of goal and scope, the inventory analysis collects information on the physical flows related to the input of resources, materials, semi-finished products, and products and the output emissions, waste and valuable

[71] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*

products for the product system. The analysis examines all processes identified as belonging to the product system, and the flows are scaled according to the product's reference flow, which is determined from the functional unit. Environmentally extended input-output analysis may be used to support and qualify the collection of inventory data. The output of the inventory analysis is the life cycle inventory, a list of quantified elementary physical flows for the product system associated with the provision of the service or function described by the functional unit (Hauschild, 2018)[72].

Based on life cycle inventory, impact assessment converts the physical flows and interventions of the product system into impacts on the environment using knowledge and models from environmental science. The impact assessment consists of five elements, the first three are mandatory according to the ISO 14040 standard:

- selection of impact categories that are exemplary of the assessment parameters that were chosen as part of the scope definition;
- classification of elementary flows from the inventory, putting them into impact categories according to their ability to contribute by affecting the chosen indicator;

[72] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*

- characterization using environmental models for the impact category to determine the ability of each of the assigned elementary flows to affect the category indicator;
- normalization is used to obtain information on the relative magnitude of each characterized value for the different impact categories by expressing them relative to a common set of reference impacts;
- grouping or weighting supports comparison among impact categories by grouping them and possibly ranking them according to their perceived severity, or by weighting them using weighting factors that provide a quantitative expression for each impact category of how severe it is compared to the other impact categories (Hauschild, 2018)[73].

The final phase of LCA study consists of the interpretation. The results of the study are interpreted to answer the questions posed in the goal definition. The interpretation takes into account both the results of the inventory analysis and the characterization of the elements of impact assessment, and possibly, normalization and weighting. The interpretation must be made taking into account the goal and scope definition and consider the constraints imposed by the scoping choices in

[73] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*

order to give meaningful interpretation of the results, for example due to geographical, temporal or technological assumptions (Hauschild, 2018)[74].

It is important to emphasize that the LCA model has some strengths as well as limitations. One strength is its comprehensiveness in terms of life cycle perspective and coverage of environmental issues. This allows comparison of the environmental impacts of product systems composed of hundreds of processes, that account for thousands of resource uses and emissions that occur in different places and at different times. However, the comprehensiveness is also a limitation, because it requires simplifications and generalizations in modelling the product system and environmental impacts that prevent LCA from calculating actual environmental impacts (Hauschild, 2018)[75]. In fact, as processes become more local and more transient, the loss of accuracy and resolution increases so that aggregated, mass-loading approaches lose relevance[76].

Another strength related to comparative assessments is that LCA follows the "best estimate" principle. This generally allows for unbiased comparisons because it means that the same level of caution is applied throughout the impact assessment modelling. However, a limitation associated with this principle is that LCA's

---

[74] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer*.

[75] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer*.

[76] Owens J. W. (1997), 'Life-Cycle Assessment: Constraints on Moving from Inventory to Impact Assessment'. Available at <https://doi.org/10.1162/jiec.1997.1.1.37> accessed 2 December 2021.

models are based on the average performance of the processes and do not support consideration of risks from rare but highly problematic events such as accidents at industrial sites (Hauschild, 2018)[77].

A final limitation concerns the fact that LCA is a good indicator for understanding which product system is better for the environment, but it cannot show whether it is "good enough". Therefore, it is wrong to conclude that a product is environmentally sustainable, in absolute terms, by referring to a LCA that shows that the product has a lower environmental impact than another product (Hauschild, 2018)[78].

Given the widespread acceptance of the triple bottom line approach, it is possible to bring this approach to the LCA methodology, getting what is called the *Life cycle sustainability assessment (LCSA)*, which is the combination of life cycle assessment (LCA), *life cycle costing (LCC)* and *social life cycle assessment (SLCA)*[79]. LCA corresponds to the environmental dimension, LCC is considered the economical dimension and SLCA deals with the social one. An important requirement of LCSA is that the three pillars of sustainability must be assessed against the same system boundaries, i.e. that the same elements of a product life cycle are considered in all

---

77 Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer*.

78 Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer*.

79 Klöepffer W. (2008), 'Life cycle sustainability assessment of products'. Available at <https://doi.org/10.1065/lca2008.02.376> accessed 3 December 2021.

three assessments[80], and also, according to Klöepffer, a decrease in one sustainability dimension, can be compensated by an increase in another dimension. Considering that the LCA has been already discussed, the focus will be placed on the LCC and SLCA.

2.2.1 LIFE CYCLE COSTING (LCC)

The life cycle cost of an item is the sum of all wealth expended to support of item from its design and manufacture through its operation to the end of its useful life (White, 1976)[81].

Life cycle costing (LCC) can be the economic pillar in a full life cycle sustainability assessment. It is a versatile technique that can be used for a range of purposes and at different stages in the project or asset life cycle to support decision-making (Hauschild, 2018)[82].

LCC is a technique that evaluates costs over the life cycle of a product or a system. Performing an LCC can serve several purposes. It can be used as a planning tool, as an optimization tool, as a tool to identify hotspots, as part of a life cycle sustainability assessment of a particular product, or to evaluate investment decisions. A consideration must be made regards the timing of analysis, where two

---

[80] Klöepffer W. (2008), 'Life cycle sustainability assessment of products'. Available at <https://doi.org/10.1065/lca2008.02.376> accessed 3 December 2021.

[81] White G. E., Ostwald P. F. (1976), 'Life cycle costing', *Management Accounting.*

[82] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*

types of LCC can be distinguished. Ex ante LCC, which is a prospective approach based on estimates, and in contrast, ex post LCC, which is a retrospective approach based on actual results. Another important consideration must be made for the target group. This can be a single actor in a value chain, or it can be the whole value chain into perspective. The choice of target group in the goal and scope definition step of the LCC has an impact on the required level of detail (Hauschild, 2018)[83].

It is possible to distinguish three variants of LCC. Conventional LCC is the original method. Environmental LCC is aligned with LCA in terms of system boundaries, function unit, and methodological steps. Societal LCC includes monetarization of other externalities, including environmental and social impacts. To make this differentiation more understandable, before it is important to make a distinction between internal and external costs. Costs sustained by actors directly involved in the life cycle of the product are called internal costs. Nevertheless, a product or system can incur other costs, borne by other actors indirectly affected by the product's life cycle, such as pollution or other social impacts, these are referred to as external costs. The latter, also referred to as externalities, are changes in value caused by a business transaction, that are not included in its price, or changes in value that occur as side effects of economic activity[84].

---

[83] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer*.

[84] Dodds K., Galtung J. (1997), 'Peace by peaceful means: peace and conflict, development and civilization'. Available at <https://doi.org/10.2307/2623565> accessed 5 December 2021.

Conventional LCC was originally developed for procurement purposes in the U.S. Department of Defence (White, 1976)[85]. LCC is primarily used as a decision-making tool, to support acquisition of capital goods and durable product with high investment costs[86]. Conventional LCC is conducted from the perspective of a single actor, who often is the user of a solution, and especially, only internal costs are examined (Hauschild, 2018)[87].

Environmental LCC (ELCC), in contrast to the single actor perspective of the conventional LCC, is suited with ISO standard 14040 and 14044 on LCA, in the way that it takes the position of a functional unit and considers the entire life cycle, including all actors in the value chain or life cycle. ELCC also differ from conventional LCC for the focus, the latter is focused on industry, instead ELCC was developed to support LCA because it covers the economic dimension, and helps identify hotspots in terms of cost and environmental impact. In addition to internal costs borne by actors, in the life cycle ELCC can be included external costs, which are expected to be internalized in the short run (Hauschild, 2018)[88].

Societal LCC (SLCC) aims to support decision-making at the societal level, including governments and public authorities. This includes quantifying

---

[85] White G. E., Ostwald P. F. (1976), 'Life cycle costing', *Management Accounting.*

[86] Hunkeler D., Lichtenvort K., Rebitzer G. (2008), 'Environmental Life Cycle Costing'. Available at <https://doi.org/10.1201/9781420054736> accessed 3 December 2021.

[87] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*

[88] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*

environmental impacts in monetary terms. SLCC also includes selected external costs by assigning them a monetary value (Hauschild, 2018)[89].

2.2.2 SOCIAL LIFE CYCLE ASSESSMENT (SLCA)

Since the beginning of this millennium the scope of LCA has been expanded to include impacts on social entities, for example consumers, communities or workers, in order to more comprehensively assess the contribution of a product or system to sustainability. This extension of LCA is known as social life cycle assessment (SLCA). The aim of SLCA is to develop a methodology, or to be more precise, a system of methods with corresponding procedural phases that, when followed, lead to an assessment of the social impact of a product during its life cycle. The initial development of SLCA was heavily influenced by LCA, with the scientific community believing that SLCA may assess social impacts in the same way that LCA can assess environmental impacts (Hauschild, 2018)[90].

It is possible to state that the main challenges in SLCA relate to the selection and analysis of social indicators, the definition of the functional unit and system boundaries, and also the impact assessment (UNEP/SETAC, 2019)[91]. According to

---

[89] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*

[90] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*

[91] UNEP/SETAC (2009), 'Guidelines for Social Life Cycle Assessment of Products', *UNEP-SETAC Life-Cycle Initiative*.

Jørgensen, physical flows hardly determine social impacts, but the latter are mainly determined by the behavior of the company towards its stakeholders[92]. As a consequence, it is the company and not the process that is the fundamental entity[93], so a relation of social aspects to a functional unit and their aggregation over the entire life cycle of the product is barely practicable[94].

2.3 ENVIRONMENTAL PERFORMANCE INDICATORS (EPIs)

An additional tool used to measure and control company's environmental results is made up of environmental performance indicators (EPIs) (Donato, 2000)[95]. EPIs are financial or non-financial metrics, that provide important information about environmental impact, regulatory compliance, organizational systems and stakeholders relations (Veleva, 2000)[96]. Environmental performance indicators refer to the measurement of the interaction between the company and the

---

[92] Jørgensen A., Le Bocq A., Nazarkina L. (2008), 'Methodologies for social life cycle assessment'. Available at <https://doi.org/10.1065/lca2007.11.367> accessed 6 December 2021.

[93] Hauschild M.Z., Dreyer L.C., Jørgensen A. (2008), 'Assessing social impacts in a life cycle perspective'. Available at <https://doi.org/10.1016/j.cirp.2008.03.002> accessed 6 December 2021.

[94] Martínez-Blanco J., Lehmann A., Muñoz P., Antón A., Traverso M., Rieradevall J., Finkbeiner M. (2014), 'Application challenges for the social Life Cycle Assessment of fertilizers within life cycle sustainability assessment'. Available at <https://doi.org/10.1016/j.jclepro.2014.01.044> accessed 6 December 2021.

[95] Donato F. (2000), 'La Variante Ambientale nelle Politiche Ambientali: Sostenibilità Economica ed Ecologica', (*The Environmental Variant in Environmental Policies: Economic and Ecological Sustainability,* English translation, ed.), *Giuffrè Editore.*

[96] Veleva V., Ellenbecker M. (2000), 'A proposal for measuring business sustainability: addressing shortcomings in existing frameworks', *Greener Management International*.

environment (Olsthoorn, 2001)[97]. Those are also a component of EMA, which is the management of environmental and economic performance through the development and implementation of proper environmental accounting system and practices[98].

Indicators quantify information by aggregating diverse and varied data (necessary to obtain reliable information). Thus, these can be used to demonstrate and communicate complex phenomena in an easier way, including trends progresses over time. Indicators must provide information on the key characteristics that influence the suitably of products and processed from a sustainability perspective[99].

The selection of environmental performance indicators is a conceptual reference of ISO standard 14031. This standard describes the indicators that must be considered when evaluating environmental performance[100]. EPIs provide data and information on environmental performance of the organization, and those are divided into three categories.

The first category is about the environmental condition indicators (ECIs), which is defined as specific expressions that give information about the local, regional,

---

[97] Olsthoorn X., Tyteca D. (2001), 'Environmental indicators for business: a review of the literature and standardization methods', *Journal of Cleaner Production.*

[98] Herni J., Journeault M. (2007), 'Environmental performance indicators: An empirical study of Canadian manufacturing firms'. Available at <https://doi.org/10.1016/j.jenvman.2007.01.009> accessed 7 December 2021.

[99] Sikdar S. K. (2003) 'Sustainable development and sustainability metrics'. Available at <https://doi.org/10.1002/aic.690490802> accessed 7 December 2021.

[100] Campos L. M. S., de Melo Heizen D. A., Verdinelli M. A., Cauchick Miguel P. A. (2015), 'Environmental performance indicators: a study on ISO 14001 certified companies'. Available at <https://doi.org/10.1016/j.jclepro.2015.03.019> accessed 7 December 2021.

national or global state of the environment. These measures include receptor indicators (for example, biological oxygen demand, ecotoxicity); sustainable indicators (for example, emissions of a substance per volume of production or per unit of value added); proxy ECIs (e.g., indicators that express emissions and waste data in terms of their ability to cause environmental damage).

The second category concerns the operational performance indicators (OPIs), which give information on the environmental performance of organization's activities. They comprehend inputs of materials, services and energy; operations of facilities and equipment and logistics; outputs of waste, emissions, products and services.

The last category is about management performance indicators (MPIs), which provide information about management's efforts to influence the environmental performance of an organization. Four subcategories are distinguished: implementation of policies and programs; conformance of actions with expectations or requirements; community relations; environmental financial performance[101].

The specific way in which these indicators are used by managers as control mechanisms, communication devices and motivation tools is fundamental. It is possible to evidence four main uses of these indicators: monitoring compliance with

[101] Herni J., Journeault M. (2007), 'Environmental performance indicators: An empirical study of Canadian manufacturing firms'. Available at <https://doi.org/10.1016/j.jenvman.2007.01.009> accessed 7 December 2021.

environmental policies and regulations, motivating continuous improvement, providing data for internal decision making and proving data for external reporting[102].

Since next chapter will focus on the transport sector, it is important to mention a particular environmental performance indicator, which concerns carbon footprint (CF)[103]. Carbon footprint is a globally standardized indicator of greenhouse gas (GHG) emissions during the life cycle stages of any goods, services or activities. Carbon footprint has become very important in both public and private sectors as a useful tool for identifying areas where emissions can be reduced and for driving the changes needed to improve the eco-profile of products and the social and environmental awareness and responsibility of people and organizations[104]. The CF commonly considers the six GHGs identified in the Kyoto Protocol, which are: carbon dioxide (CO2); methane (CH4); nitrous oxide (N2O); hydrofluorocarbons (HFC); perfluorocarbons (PFC); sulfur hexafluoride (SF6)[105].

---

[102] Herni J., Journeault M. (2007), 'Environmental performance indicators: An empirical study of Canadian manufacturing firms'. Available at <https://doi.org/10.1016/j.jenvman.2007.01.009> accessed 7 December 2021.

[103] Finkbeiner M. (2009), 'Carbon footprinting—opportunities and threats'. Available at <https://doi.org/10.1007/s11367-009-0064-x> accessed 7 December 2021.

[104] Rugani B., Vázquez-Rowe I., Benedetto G., Benetto E. (2013), 'A comprehensive review of carbon footprint analysis as an extended environmental indicator in the wine sector'. Available at <https://doi.org/10.1016/j.jclepro.2013.04.036> accessed 7 December 2021.

[105] Laurent A., Olsen S. I., Hauschild M. Z. (2010), 'Carbon footprint as environmental performance indicator for the manufacturing industry'. Available at <https://doi.org/10.1016/j.cirp.2010.03.008> accessed 7 December 2021.

CHAPTER 3 – MEASURING AND MONITORING THE ENVIRONMENTAL IMPACT IN THE MOBILITY MARKET: DIFFERENCES BETWEEN CONVENTIONAL AND ELECTRIC MEANS OF TRANSPORTATION

3.1 TRANSPORT AND ENVIRONMENT

Over the last century, the transport of people and goods has extremely increased, reflecting the clear economic and social benefits of transport. The global economy functions through international trade and travel, and there are important positive links between transport and economy, in fact, the growth of one stimulates the other (Rietveld, 1998)[106]. Transportation not only enables other sectors of the economy to function, but has itself become a fundamental sector of the global economy[107].

3.1.1. CONVENTIONAL MOBILITY

In order to travel further, more often and with limitless freedom, cheap natural resources, for example oil, have enabled people, businesses and other stakeholders around the world (especially in developed countries) to take advantage of

[106] Rietveld P., Bruinsma F. (1998), 'Is Transport Infrastructure Effective? Transport Infrastructure and Accessibility: Impacts of the Space Economy', *Springer*.
[107] European Commission, Directorate-General for Energy and Transport (2010), ' EU energy and transport in figures: statistical pocketbook'. Available at <https://data.europa.eu/doi/10.2768/19814> accessed 17 December 2021.

transportation. But, relentless travel and movement come at a price, in fact, modern transport is almost entirely dependent of oil[108].

As traffic demand has grown, numerous problems have arisen. The problems concern traffic congestion, urban sprawl, traffic safety and environmental problems, which are the most interesting for the purpose of this thesis. The main environmental problems related to this sector are concerning with noise, air pollution, greenhouse gas (GHG) emissions and ecosystem impacts[109]. Growing transport demand has also increased and accentuated concerns about oil scarcity, oil price volatility and energy security. Although these issues were initially discussed in the wake of the 1973 oil crisis, those have gained attention in the 2000s. In addition, other sector of the economy can increasingly rely on alternatives, such as renewable energy resources, there are few alternative options for transportation. All of these issues are problematic in their own right, with different characteristics and impacts, but it is possible to consider greenhouse gas emissions to be the most pressing environmental issue[110].

---

[108] Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.

[109] Scholl L., Schipper L., Kiang N. (1996) 'CO2 emissions from passenger transport: A comparison of international trends from 1973 to 1992'. Available at <https://doi.org/10.1016/0301-4215(95)00148-4> accessed 17 December 2021.

[110] Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.

Climate models indicate that emissions in 2050 should be 50-80% lower than 1990 to limit changes in global temperature to 2-2.4°C above the preindustrial levels[111]. Transport is the only major sector where emissions continue to increase, with passenger car transport, road and sea freight, and air transport being the main sources of GHG emissions[112].

There is not a standard way in which sustainable transportation is being considered, even if nowadays the environmental problem is the most problematic, according to the triple bottom line approach, decisions must be taken also considering the economic and social aspects (Env. Can., 2003)[113]. There are several environmental problems, some of those were already mentioned previously, that are key elements in order to make understandable why the transport system is not sustainable, for example the diminishing of petroleum reserves is one of those. If we look only at conventional sources, some experts believe that we have already discovered and largely exploited all the world's major oil fields. If more are found, the world's oil producers could mount a delaying action (Deffeyes, 2010)[114]. Others argue that liquid fuels production will be sufficient to meet the demand well into the 21st

---

[111] Intergovernmental (IPCC) (2007), 'Climate Change 2007: Synthesis Report: Summary for Policy-makers. Available at <https://www.ipcc.ch/site/assets/uploads/2018/02/ar4_syr_spm.pdf> accessed 17 December 2021.

[112] Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.

[113] Environment Canada (2003), 'Environment signals: Canada's National Environmental Indicator Series'.

[114] Deffeyes K. S. (2001), 'The Impending World Oil Shortage'.

century, as rising prices spur new discoveries, improved extraction and the development of non-conventional resource such as oil sands[115]. At the end of the day, our current transport systems are not sustainable because, at least currently, they primarily use a fuel that is finite, non-renewable and rapidly running out (Black, 2010)[116].

Another issue regards global atmospheric impacts. Some scientists believe that humans are releasing emissions into the atmosphere that will eventually have catastrophic effects on world's climate. Many of them believe that effects have already begun, with noticeably higher global temperatures and measurable sea-level rise. Increased emissions of so called greenhouse gases may lead to an amplification of the "greenhouse effect". More specifically, the increased burning of fossil fuels has released significant amounts of carbon-dioxide, a greenhouse gas into the atmosphere, causing the average global temperature to rise[117].

In 2001, carbon dioxide concentration were 31% higher than in 1750 and are now higher than they have been in 420.000 years[118]. Since the use of petroleum-based fuels in transportation is responsible for about one-third of these emissions, our

---

[115] Sorrell S., Speirs J., Bentley R., Brandt A., Miller R. (2010), 'Global oil depletion: A review of the evidence'. Available at <https://doi.org/10.1016/j.enpol.2010.04.046> accessed 17 December 2021.

[116] Black W. R. (2010), 'Sustainable Transportation: Problems and Solutions', *Guilford Press*.

[117] Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.

[118] IPCC (2001), 'Climate Change 2001: The Scientific Basis'. Available at <https://www.ipcc.ch/site/assets/uploads/2018/03/WGI_TAR_full_report.pdf> accessed 17 December 2021.

current transportation system is demonstrably unsustainable by this definition. The general consensus about the consequences of the global atmosphere impact is that the global temperatures will rise, and even small changes in temperatures can have significant negative impacts. Although many sectors of the economy or society may remain relatively unaffected for a time, transportation is not one of them. Transit tunnels flooding due to sea level rise, airplanes not taking off due to high temperatures, highways and railroad tracks buckling due to excessive heat, coastal highway and rail flooding, and port flooding are not problems that can be easily dismissed[119]. More importantly, the potential shift of agricultural production to new areas with temperate climates and away from areas that are too hot or too dry, would result in the need to relocate and redesign transportation infrastructure in these areas (Black, 1990)[120].

A different issue concerns the emissions from motor vehicles, that are a significant contributor to urban air quality problems. A significant portion of urban ozone production also comes from mobile sources. These negative health effects of these emissions, particularly on the human respiratory system, must be seen as a significant problem that cannot be left alone. While some countries made

---

[119] Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.

[120] Black W. R. (1990), 'Global Warming: Impacts on the Transportation Infrastructure', *Transportation Research Board*.

considerable progress in reducing these emissions, it is still currently a major factor that makes the current transport system unsustainable[121].

One major difference between sustainable transportation in the United States and in Europe is that people in Europe are more concerned about noise. Numerous studies indicate that loud and continuous noise is detrimental to human health. This damage can be psychological, leading to nervousness and behavioral problems. It can also be physiological, leading to serious consequences such as heart disease. As a result, many European countries are trying to reduce noise levels, especially in urban area. Of course, transport systems in North America have the same psychological and physiological effects and researchers are working to minimize them[122].

The need to protect our biological resources from the damage caused by transportation has attracted much attention[123]. The most devastating and high-profile transportation incidents affecting biological resources are the oil spills caused by the breakup of oil tankers, which dump countless barrels of oil into the ocean or waterway. It is quite clear that the major consequences will affect marine

---

121 Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.

122 Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.

123 Transportation Research Board (1997), 'Toward A Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology - Special Report 251'. Available at <https://doi.org/10.17226/11390> accessed 17 December 2021.

fauna, but long stretches of beach are also often devastated over months or even years[124].

The last issue regards equity. Some researchers who have examined what makes the transport system unsustainable have focused on issues of equity[125], that is, the notion that the operation of current transport system should not compromise the ability of future generations to adequately meet their transportation needs. This notion of equity does not mean that future generations should necessarily have the same kind of transport system that we have today, but simply that if we continue with a system based on finite petroleum reserves, we should have either sufficient fuel available for those future generations. In this way, we would avoid profound shocks to the social and economic system on which we depend[126].

Considering all the issues analyzed before, it is possible to deduce that a sustainable transport system provides transportation and mobility using renewable fuels while minimizing emissions harmful to the local and global environment. With the aim of understand which kind of mean of transportation is the most sustainable, it is fundamental to make a clear comparison between conventional (fuel-powered) and

---

124 Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.

125 Feitelson E. (2002), 'Introducing environmental equity dimensions into the sustainable transport discourse: issues and pitfalls'. Available at <https://doi.org/10.1016/S1361-9209(01)00013-X> accessed 17 December 2021.

126 Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.

electric transport systems. Although there are different alternatives relative to these two types of transportation (for example hybrid engines), it is more clear to highlight the differences between these two, also avoiding the risk of being too dispersive.

3.1.2. ELECTRIC MOBILITY

Nowadays the answer to all these problems would seem from the electric mobility, but is it really this? Electric mobility (or e-mobility) is an emerging and important topic, relevant both to the efficient use of energy for mobility, and to addressing the challenges of sustainability. Developing sustainable strategies for efficient use of energy resources requires a comprehensive assessment of three pillars of sustainability. From a social and economic perspective, the widespread adoption of electric vehicles is expected to cause structural change in the energy industry, ranging from employment shifts in the supply chain of the various energy sectors (shifting from petroleum to electricity generation) to tax balances and profitability. From an environmental and economic perspective, there are still questions about the potential benefits of electric vehicle technologies. In this regard, government intervention is extremely important[127]. Sustainable energy development plans for

[127] Nilsson M., Nykvist B. (2016), 'Governing the electric vehicle transition – Near term interventions to support a green energy economy'. Available at <https://doi.org/10.1016/j.apenergy.2016.03.056> accessed 20 December 2021.

governments and the use of renewable energy sources are important strategies to maximize the potential environmental benefits that can be achieved through the widespread adoption of electric vehicles[128]. The potential environmental benefits that could result from the adoption of these technologies are highly dependent on the source of electricity generation[129]. For example, the adoption of such technologies in regions that rely primarily on coal or petroleum for electricity generation could be worse than the use of fossil fuel vehicles[130]. Therefore, developing strategies for the adoption of electric vehicle technologies requires sound, informed decision based on a comprehensive sustainability assessment[131].

Taking into consideration the European model, there are some goals set by EU with the purpose of developing electric mobility. One of those concerns *Transport 2050* strategy, which aim to address the issue of increased greenhouse gas emissions, and reduce Europe's dependence on oil imports (European Commission, 2011)[132].

---

128 Nienhueser I. A., Qiu Y. (2016), 'Economic and environmental impacts of providing renewable energy for electric vehicle charging – A choice experiment study'. Available at <https://doi.org/10.1016/j.apenergy.2016.07.121> accessed 20 December 2021.

129 Onat N. C., Kucukvar M., Tatari O. (2015), 'Conventional, hybrid, plug-in hybrid or electric vehicles? State-based comparative carbon and energy footprint analysis in the United States'. Available at <https://doi.org/10.1016/j.apenergy.2015.04.001> accessed 20 December 2021.

130 Onat N. C., Kucukvar M., Tatari O. (2015), 'Conventional, hybrid, plug-in hybrid or electric vehicles? State-based comparative carbon and energy footprint analysis in the United States'. Available at <https://doi.org/10.1016/j.apenergy.2015.04.001> accessed 20 December 2021.

131 Onat N. C., Kucukvar M., Aboushaqrah N. N. M., Jabbar R. (2019), 'How sustainable is electric mobility? A comprehensive sustainability assessment approach for the case of Qatar'. Available at <https://doi.org/10.1016/j.apenergy.2019.05.076> accessed 20 December 2021.

132 European Commission (2011), 'A Growth Package for Integrated European Infrastructures: Communication from The Commission to The European Parliament, The Council, The European Court of Justice, The Court Of Auditors, The European Investment Bank, The European Economic and Social Committee and to the Committee of the Regions'.

Accordingly, the goal is to halve the use of conventionally fueled passenger cars by 2030, to make urban freight transport CO2 free, and to completely ban conventionally fueled passenger from cities by 2050. In line with the Transport 2050 strategy, the European Commission has recently presented a European strategy low-emission mobility (European Commission, 2016)[133]. This strategy aims to reduce Europe's dependence on oil imports while increasing innovation and competitiveness. For the commercial sector, for example, reducing CO2 emissions caused by freight logistics, while ensuring an efficient urban freight transport system is a major concern[134].

A further goal concerns infrastructure. Given that energy demand is increasing with the growing use of e-vehicles, the EU's directive requires member states to ensure that charging stations for electric vehicles are publicly accessible and provide sufficient coverage. The EU's goal is to create a charging infrastructure with one charging point per 10 e-vehicles, in order to guarantee levels of usage. The main goal is that electric vehicle owners can charge their vehicles throughout Europe without obstacles[135]. Another goal is the interoperability and standardization of e-

---

133 European Commission (2016), 'Implementing the Energy Performance of Buildings Directive 2016, Country Reports'.

134 Quak H., Nesterova N., Rooijen T. v. (2016), 'Possibilities and Barriers for Using Electric-powered Vehicles in City Logistics Practice, Transportation Research Procedia'. Available at <https://doi.org/10.1016/j.trpro.2016.02.055> accessed 20 December 2021.

135 Biresselioglu M. E., Kaplan M. D., Yilmaz B. K. (2018), 'Electric mobility in Europe: A comprehensive review of motivators and barriers in decision making processes'. Available at <https://doi.org/10.1016/j.tra.2018.01.017> accessed 20 December 2021.

mobility to facilitate the charging of electric vehicles throughout Europe (European Commission, 2010)[136]. A charging plug standard for cars already exists, but the next phase is to introduce such a standard for electric buses and motorcycles (European Commission, 2010)[137].

The last main goal of EU regards electric market design. This goal aim to achieve zero-emission transport by 2050, for both passengers, and commercial transport. However, as we said before, the emission reduction achieved by the introduction of electric vehicles is highly dependent on the power source used[138]. This source of electricity could be achieved by nuclear power or renewable energy sources[139]. Therefore, to optimize the impact on CO2 emissions, the electricity source for vehicles charging should come from renewable sources such as wind and sun[140]. According to a 2012 study by the Oeko-Institut, there will be an increase in renewable energy in the future, but according to their model calculation, the tal amount projected for 2030 would not be sufficient to meet the increased demand

---

136 European Commission (2010), 'A European Strategy on Clean and Energy Efficient Vehicles: Communication from The Commission to The European Parliament, The Council and The European Economic and Social Committee'.

137 European Commission (2010), 'A European Strategy on Clean and Energy Efficient Vehicles: Communication from The Commission to The European Parliament, The Council and The European Economic and Social Committee'.

138 Kannan R., Hirschberg S. (2016), 'Interplay between electricity and transport sectors – Integrating the Swiss car fleet and electricity system', *Transportation Research Part A: Policy and Practice.* Available at <https://doi.org/10.1016/j.tra.2016.10.007> accessed 21 December 2021.

139 European Environment Agency (EEA) (2016), ' Electric Vehicles in Europe'. Available at <https://www.eea.europa.eu/publications/electric-vehicles-in-europe> accessed 21 December 2021.

140 Usmani O. A. (2015), 'Policy recommendations and stakeholder actions towards effective integration of EVs in the EU'. Available at <http://resolver.tudelft.nl/uuid:e2ac5ae6-885a-4147-86c9-c92a733d3fe1> accessed 21 December 2021.

from electric vehicles[141]. As the EU seeks to phase out nuclear power, electricity companies face the challenge of meeting increased energy demand by expanding renewables from wind, sun and water. To address this issue, the European Commission wants to link transport and energy sectors. This linkage is particularly important, because, as electricity consumption in the transportation sector increases, challenges may arise in meeting demand. In 2010, the European Commission proposed the "Electric Market Design", which aims to promote charging when cheap electricity is available, for example when demand is low or supply is high (European Commission, 2010)[142].

3.2 ENVIRONMENTAL MANAGEMENT SYSTEM (EMS) IN THE MOBILITY MARKET: COMPARISON BETWEEN ICEVs AND BEVs

In order to better understand what are the environmental impacts of conventional and electric means of transportation, it is necessary to use two different tools that were discussed in the previous chapter, the life cycle assessment (LCA) method and some environmental performance indicators (EPIs). To avoid making mistakes by

[141] Oeko-Institut (2012), 'Are electric vehicles the mode of the future? Potentials and environmental impacts'. Available at <https://www.oeko.de/oekodoc/1350/2012-002-en.pdf> accessed 21 December 2021.

[142] European Commission (2010), 'A European Strategy on Clean and Energy Efficient Vehicles: Communication from The Commission to The European Parliament, The Council and The European Economic and Social Committee'.

comparing different types of transportation, the focus will be placed in the automotive sector.

The environmental impact of an electric vehicle plays an important role in its market acceptance and is one of the main reasons for its development. As such, life cycle assessment in the field of electric mobility can be used to answer some challenges: comparison between different types of e-vehicles and internal combustion engine vehicles; the impact of the energy mix used to power the vehicles; the evaluation of weight reduction strategies; the analysis of the combustion on the traction battery to the overall environmental impact of a e-vehicle; the analysis of disposal scenarios, especially with respect to the treatment of the main components, in particular the batteries, electric motors, and the car body (Hauschild, 2018)[143].

The goal of LCA is to evaluate and compare environmental impacts related to the production, use, and disposal of electric and conventional vehicles. This analysis assumes that both ICEVs (internal combustion engine vehicles) and BEVs (battery electric vehicles) can drive 150,000 km, and the environmental impacts are calculated for such a life cycle, ensuring that no battery replacement is required[144].

---

[143] Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer*.

[144] Petrauskienė K., Skvarnavičiūtė M., Dvarionienė J. (2020), 'Comparative environmental life cycle assessment of electric and conventional vehicles in Lithuania'. Available at <https://doi.org/10.1016/j.jclepro.2019.119042> accessed 3 January 2022.

The scope of this analysis represents a "complete LCA", that includes the fuel cycle as a "Well-To-Wheel" (WTW) analysis and the vehicle life cycle that follows a "Cradle-To-Grave" approach. The WTW phases include the extraction of energy resources, the production and distribution of energy sources, and the conversion of energy in the vehicle. The cradle-to-grave approach includes material production, equipment manufacturing, maintenance, and End-of-Life (EoL) of the vehicle and road infrastructure. The final phase, the End-of-Life cycle, includes the dismantling and recycling of the vehicle parts, and the shredding, recycling and disposal of the residues[145].

Life cycle inventory (LCI) phase consists with the collection and processing of all data. It represents the exchanges with the ecosphere triggered during vehicle life cycle: energy and raw materials; waterborne emissions; solid wastes; atmospheric emissions; and other releases attributed to car life cycle are quantified and assigned to the defined functional unit[146].

Production includes the entire construction process, from the extraction of raw materials to the manufacture of vehicle components. For this phase, data collection consists in determining the type and quantity of materials and the manufacturing

---

145 Petrauskienė K., Skvarnavičiūtė M., Dvarionienė J. (2020), 'Comparative environmental life cycle assessment of electric and conventional vehicles in Lithuania'. Available at <https://doi.org/10.1016/j.jclepro.2019.119042> accessed 3 January 2022.

146 Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

processes for each vehicle component. For this purpose, the reference vehicle alliance is divided into assemblies, components and mono-material parts through a breakdown approach[147].

The use includes both subphases of vehicle operation, namely energy production and emission during operation. The first concerns all conversion processes upstream of fuel consumption: fuel production from feedstock extraction or production, transportation, conversion of feedstock to final fuel and subsequent storage, distribution and delivery to the vehicle tank. Quantification of energy supply chain impacts is based on resource depletion and emissions from the production of fuel (internal combustion engine vehicle) and electricity (battery electric vehicle) during operation.

Environmental impacts of the End-of-Life phase are modelled considering energy consumption for dismantling, recycling, landfilling, credits from recyclables and energy flows, and releases to the environment due to waste landfilling[148].

Life cycle impact assessment (LCIA) shows the results for both ICEVs and BEVs. Additionally to the LCA, contributors of production, use and EoL phases, it will be also reported some indicators, which are considered as being relevant in mobility

[147] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

[148] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

sector. These indicators concern acidification, climate change (including biogenic carbon), human toxicity (non-cancer effects), particulate matter (respiratory inorganics), photochemical ozone formation, and resource depletion, mineral, fossils and renewables[149].

For what concerns climate change, most of the impact of ICEVs is due to the high level of pollution associated with the use phase. Exhaust gas emissions during operation represent the main contributor to use while the remaining part is due to the fuel supply chain. The impact of ICEV production is almost evenly distributed among the assemblies, which have a predominant share of metal materials, with small shares of electrics/electronics and interior. On the other hand, the environmental impact of BEVs is mainly due to the production and use phases, with a slightly higher share of the second phase. The impact of BEV production is definitely higher than ICEV, while the attribution of climate change to specific vehicle assemblies shows that the powertrain has the greatest impact. This is due to the high contribution of battery and electric motor production as well as other powertrain components (inverter and passive battery cooling system) which have a high aluminum content. However, the greater impact of BEV manufacturing is largely offset by the lower impact of the use phase, resulting much lower than

---

[149] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

ICEV. This is due to the absence of exhaust gas emissions during operation and the lower environmental impact of electricity generation in relation to the fuel supply chain[150].

As regards other impact categories, the acidification impact of BEV is significantly higher than that of ICEV. This is primarily due to the high proportion of high-voltage battery and motor production, which uses a significant amount of aluminum, copper and nickel. In the case of internal combustion engine vehicles, acidification is evenly distributed between the production and the use phases. Most of the production impact is due to emissions generated during the production of platinum for the manufacture of the exhaust catalyst system. The environmental impact in the use phase, on the other hand, is mainly caused by SO2 (Sulphur dioxide) emissions during operation, while fugitive emissions from the fuel supply chain determine the remaining share[151].

The impact of BEV on human toxicity is about five times greater compared to ICEV. This is almost entirely due to the production phase. In particular, emission form extraction of raw materials and the production of chemicals and metals (aluminum, copper, platinum and nickel) used in the electric powertrain (lithium

[150] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

[151] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

battery, electric motor and power electronics) are primarily responsible for the toxicological impact. Similar to BEVs, the production phase of ICEVs has by far the highest share, with the main influential vehicle assemblies being doors/closures, powertrain, and suspension/chassis. On the other hand, usage has a small share of the total LCA impact[152].

For particular matter, a similar trend as for human toxicity is evident. Again, BEV pollution is more than twice that of ICEV, and the impact is dominated by the production phase for both propulsion technologies. The contribution of the use phase cannot be neglected, as it account almost half of LCA impact for conventional configuration, instead it is a small percentage for the electric configuration, with the use phase of ICEV evenly distributed between fuel supply and operation emissions. The notable impact of BEV production is due to the supply chain of metals, with the most important assembly being the powertrain, while emissions from coal power plants during electricity generation are the largest contributor to the use phase[153].

For what concerns photochemical ozone formation, the impact of BEV is slightly higher than that of ICEV. For both propulsion technologies, NOx (nitrogen oxides)

---

[152] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

[153] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

emissions are the main contributors to the impact. For ICEV, most influential LCA phase is use, with the share of fuel production (refining and fossil fuel distribution) comparable to emissions during operation. For BEVs, on the other hand, the impact is dominated by production, where the most important assembly is the powertrain, with blasting in mining being the main cause. For both powertrain technologies, production covers almost the entire resource use impact category, with the largest contribution coming from powertrain. The total impact LCA of BEVs is higher than ICEVs due to the heavy reliance of the electric powertrain on rare metals[154].

Battery engine vehicles have the potential to significantly reduce climate change impacts compared to internal combustion engine vehicles. However, this is only true if the electricity consumed by car is generated from non-fossil energy sources. In contrast, using fossil fuels to generate electricity can greatly reduce the environmental benefits of BEVs and even lead to an increase in greenhouse gas emissions. In this case, only a local reduction in pollution can be achieved and emissions are shifted off the road to specific areas, rather than achieving an effective reduction on a global scale. Consequently, electric mobility should only be strongly promoted in areas where electricity is mainly generated from clean energy sources. In contrast, in areas with an electricity grid characterized by a high share of coal

[154] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

power, BEVs could be counterproductive, and limiting the use phase exhaust gas emissions of conventional cars appears to be the most effective strategy for reducing impacts. However, it should be noted that the share of renewable energy in the electricity mix will gradually increase in the near future, increasing the potential of electromobility to reduce global warming and fossil fuel consumption[155].

That said, basing the comparative analysis only on the category of climate change impact, it may fail to identify some important differences between BEVs and ICEVs, leading to erroneous general conclusions. Indeed electric cars appear to have higher LCA impacts on acidification, human toxicity, particulate matter, photochemical ozone formation, and resource depletion. The main reason for this is the significant environmental impact in the manufacturing phase, mainly due to the toxicological effects closely related to the extraction of precious metals as well as the production of chemicals for battery production. To avoid shifting problems from one category of impact to another, the greatest room for improvement in BEVs lies in the technological development of innovative processes for battery production that offer high efficiencies, innovative eco-efficient materials, and component recyclability. Considering the use phase, a viable way to improve the eco-efficiency

[155] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

of BEVs is to increase the mileage LCA, which would further reduce the specific impact (for example, per kilometer impact)[156].

Finally, it can be said that market penetration of BEVs would occur with consideration of several conflicting issues, which are: vehicle manufacturing, electricity grid mix composition, high voltage battery production, and LCA mileage. These issues are key aspects to be considered when evaluating the environmental effects associated with substituting electric cars for conventional ones[157].

[156] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

[157] Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.

CONCLUSIONS

The thesis has shown that, there are differences between how EVs and ICEVs pollute the environment. According to the life cycle perspective, electric vehicles are definitely much more polluting than internal combustion engine vehicles in the production phase, instead vice versa in the use phase. Another finding concerns the potential environmental benefits that could result from the adoption of electric vehicles, which are highly dependent on the source of electricity generation, because the adoption of such vehicles, that for example are powered using primarily coal or petroleum for electricity generation, it could be even worse than the direct use of internal combustion engine vehicles. However, it must be mentioned that is important to keep pushing on the electric mobility, considering also the fact that the share of renewable energy in the electricity mix will gradually increase in the near future, increasing the potential of electromobility to reduce global warming and fossil fuel consumption. The use of nuclear energy could also be an option, because it can guarantee a large amount of energy with having a low environmental impact. The last consideration concerns infrastructures, which must be improved in order to facilitate the use of electric vehicles, because even if currently there are not so many benefits regarding electric mobility, international policies are increasingly oriented towards a sustainable and green economy, for this reason, there will be benefits in the near future.

REFERENCES:

WEB REFERENCES:

- Aras G., Crowther D. (2008), 'Governance and sustainability: An investigation into the relationship between corporate governance and corporate sustainability'. Available at <https://doi.org/10.1108/00251740810863870> accessed 5 October 2021.
- Atkinson G., Mourato S. (2008), 'Environmental Cost-Benefit Analysis'. Available at <https://doi.org/10.1146/annurev.environ.33.020107.112927> accessed 18 October 2021.
- Banister D., Anderton K., Bonilla D., Givoni M., Schwanen T. (2011), 'Transportation and the Environment'. Available at <https://doi.org/10.1146/annurev-environ-032310-112100> accessed 17 December 2021.
- Biresselioglu M. E., Kaplan M. D., Yilmaz B. K. (2018), 'Electric mobility in Europe: A comprehensive review of motivators and barriers in decision making processes'. Available at <https://doi.org/10.1016/j.tra.2018.01.017> accessed 20 December 2021.
- Brandi C., A. Dzebo, H. Janetschek (2017), 'The case for connecting the implementation of the Paris Climate Agreement and the 2030 Agenda for

Sustainable Development'. Available at <https://www.econstor.eu/handle/10419/199809> accessed 5 November 2021.

- Brundtland G. (1987), 'Our Common Future-Call for Action'. Available at <https://www.cambridge.org/core/journals/environmental-conservation/article/abs/our-common-futurecall-for-action/65808D6676E07552EF891DF31C3DF7A1> accessed 5 October 2021.
- Campos L. M. S., de Melo Heizen D. A., Verdinelli M. A., Cauchick Miguel P. A. (2015), 'Environmental performance indicators: a study on ISO 14001 certified companies'. Available at <https://doi.org/10.1016/j.jclepro.2015.03.019> accessed 7 December 2021.
- Del Pero F., Delogu M., Pierini M. (2018), 'Life Cycle Assessment in the automotive sector: a comparative case study of Internal Combustion Engine (ICE) and electric car'. Available at <https://doi.org/10.1016/j.prostr.2018.11.066> accessed 3 January 2022.
- Delmas M. A., Montes-Sancho M. (2011), 'An Institutional Perspective on the Diffusion of International Management System Standards: The Case of the Environmental Management Standard ISO 14001', *Business Ethics Quarterly*. Available at <https://www.cambridge.org/core/journals/business-ethics-quarterly/article/abs/an-institutional-perspective-on-the-diffusion-of-international-management-system-standards-the-case-of-the-environmental-

management-standard-iso-14001/5F232210367B7919498C501900970004> accessed 13 November 2021.

- Dodds K., Galtung J. (1997), 'Peace by peaceful means: peace and conflict, development and civilization'. Available at <https://doi.org/10.2307/2623565> accessed 5 December 2021.
- Dzebo A., Janetschek H., Brandi C., Iacobuta G. (2019), 'Connections between the Paris Agreement and the 2030 Agenda'. Available at <https://www.sei.org/wp-content/uploads/2019/08/connections-between-the-paris-agreement-and-the-2030-agenda.pdf> accessed 6 November 2021.
- Epstein J.M., A.R. Buhovac, K. Yuthas (2015), 'Managing Social, Environmental and Financial Performance Simultaneously'. Available at <https://www.sciencedirect.com/science/article/pii/S0024630112000726> accessed 18 October 2021.
- European Commission, 'Climate Change Consequences'. Available at <https://ec.europa.eu/clima/climate-change/climate-change-consequences_en> accessed 3 October 2021.
- European Commission, Directorate-General for Energy and Transport (2010), ' EU energy and transport in figures: statistical pocketbook'. Available at <https://data.europa.eu/doi/10.2768/19814> accessed 17 December 2021.

- European Environment Agency (EEA) (2016), ‘ Electric Vehicles in Europe’. Available at <https://www.eea.europa.eu/publications/electric-vehicles-in-europe> accessed 21 December 2021.
- Feitelson E. (2002), ‘Introducing environmental equity dimensions into the sustainable transport discourse: issues and pitfalls’. Available at <https://doi.org/10.1016/S1361-9209(01)00013-X> accessed 17 December 2021.
- Finkbeiner M. (2009), ‘Carbon footprinting—opportunities and threats’. Available at <https://doi.org/10.1007/s11367-009-0064-x> accessed 7 December 2021.
- Forbes, ‘Organizations Are Feeling The Pain Of Climate Change: Here are Five Ways It’s Affecting Their Business’. Available at <https://www.forbes.com/sites/deloitte/2021/04/16/organizations-are-feeling-the-pain-of-climate-change-here-are-five-ways-its-affecting-their-business/?sh=579f31784e0c> accessed 3 October 2021.
- Forbes, ‘Why Corporate Strategies Should Be Focused On Sustainability’. Available at <https://www.forbes.com/sites/forbesbusinesscouncil/2021/02/10/why-corporate-strategies-should-be-focused-on-sustainability/?sh=ce632b87e9f2> accessed 24 October 2021.

- Gidey E., Beshah B. (2014), 'The Plan-Do-Check-Act Cycle of Value Addition. Available at <http://dx.doi.org/10.4172/2169-0316.1000124> accessed 6 November 2021.
- Goodland R. (1995), 'The Concept of Environmental Sustainability'. Available at <https://doi.org/10.1146/annurev.es.26.110195.000245> accessed 10 October 2021.
- Hák T., Janoušková S., Moldan B (2016) 'Sustainable Development Goals: A need for relevant indicators'. Available at <https://doi.org/10.1016/j.ecolind.2015.08.003> accessed 5 November 2021.
- Harvard Business School Online, 'Why You Need Sustainability In Your Business Strategy'. Available at <https://online.hbs.edu/blog/post/business-sustainability-strategies> accessed 24 October 2021.
- Hauschild M.Z., Dreyer L.C., Jørgensen A. (2008), 'Assessing social impacts in a life cycle perspective'. Available at <https://doi.org/10.1016/j.cirp.2008.03.002> accessed 6 December 2021.
- Herni J., Journeault M. (2007), 'Environmental performance indicators: An empirical study of Canadian manufacturing firms'. Available at <https://doi.org/10.1016/j.jenvman.2007.01.009> accessed 7 December 2021.
- Hubbard G. (2006), ' Measuring Organizational Performance: Beyond The Triple Bottom Line'. Available at <https://doi.org/10.1002/bse.564> accessed 13 October 2021.

- Hunkeler D. (2016), ‘Life Cycle Assessment (LCA): A Guide to Best Practice’. Available at <https://doi.org/10.1007/s11367-016-1083-z> accessed 23 November 2021.
- Hunkeler D., Lichtenvort K., Rebitzer G. (2008), ‘Environmental Life Cycle Costing’. Available at <https://doi.org/10.1201/9781420054736> accessed 3 December 2021.
- Intergovernmental (IPCC) (2007), ‘Climate Change 2007: Synthesis Report: Summary for Policy-makers. Available at <https://www.ipcc.ch/site/assets/uploads/2018/02/ar4_syr_spm.pdf> accessed 17 December 2021.
- IPCC (2001), ‘Climate Change 2001: The Scientific Basis’. Available at <https://www.ipcc.ch/site/assets/uploads/2018/03/WGI_TAR_full_report.pdf> accessed 17 December 2021.
- Jørgensen A., Le Bocq A., Nazarkina L. (2008), ‘Methodologies for social life cycle assessment’. Available at <https://doi.org/10.1065/lca2007.11.367> accessed 6 December 2021.
- Kannan R., Hirschberg S. (2016), ‘Interplay between electricity and transport sectors – Integrating the Swiss car fleet and electricity system’, *Transportation Research Part A: Policy and Practice.* Available at <https://doi.org/10.1016/j.tra.2016.10.007> accessed 21 December 2021.

- Keohane R. O., D. G. Victor (2016), 'Cooperation and Discord in Global Climate Policy'. Available at <https://depts.washington.edu/envirpol/wp-content/uploads/2016/04/coll_Victor_paper.pdf> accessed 8 November 2021.
- Klöepffer W. (2008), 'Life cycle sustainability assessment of products'. Available at <https://doi.org/10.1065/lca2008.02.376> accessed 3 December 2021.
- Kumar S, Kumar N, Vivekadhish S. (2016), 'Millennium Development Goals (MDGS) to Sustainable Development Goals (SDGS): Addressing Unfinished Agenda and Strengthening Sustainable Development and Partnership'. Available at <https://www.ijcm.org.in/text.asp?2016/41/1/1/170955> accessed 5 November 2021.
- Laurent A., Olsen S. I., Hauschild M. Z. (2010), 'Carbon footprint as environmental performance indicator for the manufacturing industry'. Available at <https://doi.org/10.1016/j.cirp.2010.03.008> accessed 7 December 2021.
- Margolis, J.D., J.P. Walsh (2003), 'Misery loves company: rethinking social initiatives by business'. Available at <https://www.jstor.org/stable/3556659> accessed 18 October 2021.
- Marrewijk M. V., Werre M. (2003), 'Multiple levels of Corporate Sustainability', Journal of Business Ethic. Available at <https://doi.org/10.1023/A:1023383229086> accessed 5 October 2021.

- Martínez-Blanco J., Lehmann A., Muñoz P., Antón A., Traverso M., Rieradevall J., Finkbeiner M. (2014), 'Application challenges for the social Life Cycle Assessment of fertilizers within life cycle sustainability assessment'. Available at <https://doi.org/10.1016/j.jclepro.2014.01.044> accessed 6 December 2021.
- Miettinen P., Hämäläinen R. P. (1997), 'How to benefit from decision analysis in environmental life cycle assessment (LCA)'. Available at <https://doi.org/10.1016/S0377-2217(97)00109-4> accessed 25 November 2021.
- Miller K. (2020), 'The Triple Bottom Line: What It Is & Why It's Important', *Harvard Business School Online*. Available at <https://online.hbs.edu/blog/post/what-is-the-triple-bottom-line> accessed 10 October 2021.
- Moldan B., S. Janoušková, T. Hák (2012), 'How to understand and measure environmental sustainability: Indicators and targets'. Available at <https://www.sciencedirect.com/science/article/pii/S1470160X11001282> accessed 10 October 2021.
- Mondini G. (2019), 'Sustainability Assessment: from Brundtland Report to Sustainable Development Goals'. Available at <https://siev.org/wp-content/uploads/2020/02/23_15-_-MONDINI_eng.pdf> accessed 3 November 2021.

- Neefjes K. (2000), 'Environments and Livelihoods: Strategies for Sustainability'. Available at <https://policy-practice.oxfam.org/resources/environments-and-livelihoods-strategies-for-sustainability-122750/> accessed 26 October 2021.
- Nienhueser I. A., Qiu Y. (2016), 'Economic and environmental impacts of providing renewable energy for electric vehicle charging – A choice experiment study'. Available at <https://doi.org/10.1016/j.apenergy.2016.07.121> accessed 20 December 2021.
- Nilsson M., Nykvist B. (2016), 'Governing the electric vehicle transition – Near term interventions to support a green energy economy'. Available at <https://doi.org/10.1016/j.apenergy.2016.03.056> accessed 20 December 2021.
- OECD (2001), 'OECD Environmental Strategy for the First Decade of the 21st Century'. Available at <https://www.oecd.org/env/indicators-modelling-outlooks/1863539.pdf> accessed 10 October 2021.
- Oeko-Institut (2012), 'Are electric vehicles the mode of the future? Potentials and environmental impacts'. Available at <https://www.oeko.de/oekodoc/1350/2012-002-en.pdf> accessed 21 December 2021.
- Onat N. C., Kucukvar M., Aboushaqrah N. N. M., Jabbar R. (2019), 'How sustainable is electric mobility? A comprehensive sustainability assessment

approach for the case of Qatar'. Available at <https://doi.org/10.1016/j.apenergy.2019.05.076> accessed 20 December 2021.

- Onat N. C., Kucukvar M., Tatari O. (2015), 'Conventional, hybrid, plug-in hybrid or electric vehicles? State-based comparative carbon and energy footprint analysis in the United States'. Available at <https://doi.org/10.1016/j.apenergy.2015.04.001> accessed 20 December 2021.
- Oslo Government Centre, 'Sustainable Development Goals'. Available at <https://www1.undp.org/content/oslo-governance-centre/en/home/sustainable-development-goals/background.html> accessed 5 November 2021.
- Owens J. W. (1997), 'Life-Cycle Assessment: Constraints on Moving from Inventory to Impact Assessment'. Available at <https://doi.org/10.1162/jiec.1997.1.1.37> accessed 2 December 2021.
- Persson A., H. Runhaar (2018), 'Conclusion: Drawing Lessons for Environmental Policy Integration and Prospects for Future Research'. Available at <https://www.researchgate.net/profile/Hens-Runhaar/publication/326101247_Conclusion_Drawing_lessons_for_Environmental_Policy_Integration_and_prospects_for_future_research/links/5e07900392851c8364a28cbd/Conclusion-Drawing-lessons-for-Environmental-Policy-Integration-and-prospects-for-future-research.pdf> accessed 8 November 2021.

- Petrauskienė K., Skvarnavičiūtė M., Dvarionienė J. (2020), ‘Comparative environmental life cycle assessment of electric and conventional vehicles in Lithuania’. Available at <https://doi.org/10.1016/j.jclepro.2019.119042> accessed 3 January 2022.
- Quak H., Nesterova N., Rooijen T. v. (2016), ‘Possibilities and Barriers for Using Electric-powered Vehicles in City Logistics Practice, Transportation Research Procedia’. Available at <https://doi.org/10.1016/j.trpro.2016.02.055> accessed 20 December 2021.
- Realyvásquez-Vargas A, Arredondo-Soto KC, Carrillo-Gutiérrez T, Ravelo G. (2018), ‘Applying the Plan-Do-Check-Act (PDCA) Cycle to Reduce the Defects in the Manufacturing Industry. A Case Study’. Available at <https://doi.org/10.3390/app8112181> accessed 13 November 2021.
- Rugani B., Vázquez-Rowe I., Benedetto G., Benetto E. (2013), ‘A comprehensive review of carbon footprint analysis as an extended environmental indicator in the wine sector’. Available at <https://doi.org/10.1016/j.jclepro.2013.04.036> accessed 7 December 2021.
- Scholl L., Schipper L., Kiang N. (1996) ‘CO_2 emissions from passenger transport: A comparison of international trends from 1973 to 1992’. Available at <https://doi.org/10.1016/0301-4215(95)00148-4> accessed 17 December 2021.

- Sikdar S. K. (2003) 'Sustainable development and sustainability metrics'. Available at <https://doi.org/10.1002/aic.690490802> accessed 7 December 2021.
- Slaper T. F., Hall T. J. (2013), 'The Triple Bottom Line: What Is It and How Does It Work?'. Available at <http://www.ibrc.indiana.edu/ibr/2011/spring/article2.html> accessed 26 October 2021.
- Sorrell S., Speirs J., Bentley R., Brandt A., Miller R. (2010), 'Global oil depletion: A review of the evidence'. Available at <https://doi.org/10.1016/j.enpol.2010.04.046> accessed 18 December 2021.
- Transportation Research Board (1997), 'Toward A Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology - Special Report 251'. Available at <https://doi.org/10.17226/11390> accessed 17 December 2021.
- Tullberg J. (2012), ' Triple bottom line – a vaulting ambition?', Business Ethics: *A European Review.* Available at <https://doi.org/10.1111/j.1467-8608.2012.01656.x> accessed 10 October 2021.
- Unesco, 'Sustainable Development'. Available at <https://en.unesco.org/themes/education-sustainable-development/what-is-esd/sd> accessed 5 October 2021.

- United Nations, 'United Nations Conference on the Human Environment, 5-16 June 1972, Stockholm'. Available at <https://www.un.org/en/conferences/environment/stockholm1972> accessed 30 October 2021.
- United Nations Climate Change, 'Nationally Determined Contributions (NDCs)'. Available at <https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs/nationally-determined-contributions-ndcs> accessed 5 November 2021.
- United Nations Global Compact, United Nations Environment Programme (UNEP), Oxfam, and World Resources Institute (WRI) (2011), 'Adapting for a Green Economy: Companies, Communities and Climate Change', a Caring for Climate Report. Available at <https://www.unglobalcompact.org/library/116> accessed 3 October 2021.
- Usmani O. A. (2015), 'Policy recommendations and stakeholder actions towards effective integration of EVs in the EU'. Available at <http://resolver.tudelft.nl/uuid:e2ac5ae6-885a-4147-86c9-c92a733d3fe1> accessed 21 December 2021.
- Vitols S. and N. Kluge (2011), 'The Sustainable Company: A New Approach to Corporate Governance'. Available at <https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.470.3563&rep=rep1&type=pdf> accessed 6 October 2021.

- Wade K., and M. Jennings (2016), ‘The Impact of Climate Change on the Global Economy’, *Schroders*. Available at <https://www.schroders.com/de/SysGlobalAssets/digital/us/pdfs/the-impact-of-climate-change.pdf> accessed 3 October 2021.
- Willianms, E. et al (2015), ‘Business and Management Studies’, Redfame Publishing, United States, Vol. 1, No. 2. Available at <https://www.academia.edu/15336658/Business_and_Management_Studies_Vol_1_No_2_September_2015> accessed 13 October 2021.
- WWF, ‘Causes of Climate Change’. Available at <https://www.wwf.org.nz/what_we_do/climateaction/causes_of_climate_change/> accessed 3 October 2021.
- Zak A. (2015), ‘Triple Bottom Line Concept in Theory and Practice’. Available at <https://www.researchgate.net/profile/Agnieszka-Zak-2/publication/281703207_Triple_bottom_line_concept_in_theory_and_practice/links/5f081c5392851c52d626999e/Triple-bottom-line-concept-in-theory-and-practice.pdf> accessed 10 October 2021.

BIBLIOGRAPHY:

- Black W. R. (1990), 'Global Warming: Impacts on the Transportation Infrastructure', *Transportation Research Board.*
- Black W. R. (2010), 'Sustainable Transportation: Problems and Solutions', *Guilford Press.*
- Cf, O. D. D. S. (2015), 'Transforming our world: the 2030 Agenda for Sustainable Development'. *United Nations: New York, NY, USA.*
- Deffeyes K. S. (2001), 'The Impending World Oil Shortage'.
- Donato F. (2000), 'La Variante Ambientale nelle Politiche Ambientali: Sostenibilità Economica ed Ecologica', (*The Environmental Variant in Environmental Policies: Economic and Ecological Sustainability,* English translation, ed.), *Giuffrè Editore*.
- Elkington J. (1997), 'Cannibals With Forks: The Triple Bottom Line of 21st Century Business', *Capstone Publishing Ltd, Oxford*.
- Environment Canada (2003), 'Environment signals: Canada's National Environmental Indicator Series'.
- European Commission (2010), 'A European Strategy on Clean and Energy Efficient Vehicles: Communication from The Commission to The European Parliament, The Council and The European Economic and Social Committee'.
- European Commission (2011), 'A Growth Package for Integrated European Infrastructures: Communication from The Commission to The European

Parliament, The Council, The European Court of Justice, The Court Of Auditors, The European Investment Bank, The European Economic and Social Committee and to the Committee of the Regions'.

- European Commission (2016), 'Implementing the Energy Performance of Buildings Directive 2016, Country Reports'.
- Gervasoni S. (2007), 'Sistemi di Gestione Ambientale' (*Environmental Management Systems,* English translation, ed.), *Hoepli.*
- Hauschild M. Z., Rosenbaum R. K, Olsen S. I. (2018), 'Life Cycle Assessment: Theory and Practice', *Springer.*
- Hoffman A. J. (2007), 'Carbon Strategies: How Leading Companies Are Reducing Their Climate Change Footprint', *University of Michigan Press.*
- Keoleian G. A., Koch J.E., Menerey D. (1995), 'Life Cycle Design Framework and Demonstration Projects'. *Environmental Protection Agency*.
- Lafratta P. (2004), 'Strumenti Innovativi per lo Sviluppo Sostenibile', (*Innovative Tools for Sustainable Development,* English translation, ed.), *FrancoAngeli.*
- Murali Krishna I. V., Manickam V. (2017), 'Environmental Management: Science and Engineering for Industry', *Elsevier*.
- Olsthoorn X., Tyteca D. (2001), 'Environmental indicators for business: a review of the literature and standardization methods', *Journal of Cleaner Production*.

- Rietveld P., Bruinsma F. (1998), 'Is Transport Infrastructure Effective? Transport Infrastructure and Accessibility: Impacts of the Space Economy', *Springer.*
- Rogers P. P., Jalal K. F., Boyd J. A. (2012), 'An Introduction to Sustainable Development', *Routledge.*
- Stead W. E., Stead J. G. (1992), 'Management for a Small Planet: Strategic Decision Making and the Environment', *Sage Publications.*
- Stijn C., E. Feijen (2007), 'Financial Sector Development and the Millennium Development Goals', *The World Bank.*
- Thompson Jr., L.M. (2007), 'Why 'short termism' may be short lived'.
- UNEP/SETAC (2009), 'Guidelines for Social Life Cycle Assessment of Products', *UNEP-SETAC Life-Cycle Initiative.*
- Veleva V., Ellenbecker M. (2000), 'A proposal for measuring business sustainability: addressing shortcomings in existing frameworks', *Greener Management International.*
- White G. E., Ostwald P. F. (1976), 'Life cycle costing', *Management Accounting.*