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Circular Economy Action Plan and End of Life Directive

Application in the Heavy Duty Industry.

Master's thesis in Management and Economics of Innovation

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Circular Economy Action Plan and End of Life Directive

Application in the Heavy-Duty Industry

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SUMMARY

Throughout the years, the European Union has enacted an enormous amount of legislation related to the automotive industry. Efforts are underway in the European Union to achieve a full Circular Economy. Regarding circularity legislation, Heavy Duty Vehicles have been overlooked or may not have been as targeted as passenger cars. Even though Heavy Duty Vehicles are excluded from the End of Life directive, and they represent a relatively small percentage of the automotive industry, a number of factors make it worthwhile to explore them further. Volvo Group, one of the key players in the market, has paid considerable attention to this issue, the Heavy Duty Vehicles industry has adopted voluntary circular activities, the second-hand market for Heavy Duty Vehicles is highly active, and the Circular Economy regulatory framework in the European Union is undergoing rapid development. A decisive aspect of this thesis focuses on End of Life because the automotive industry already has a directive regarding End of Life which excludes Heavy Duty Vehicles. Also, the End-of-Life phase must be considered when transitioning to a circular economy. This thesis draws upon three main concepts, namely the Circular Economy concept, the End-of-Life directive, and the Circular Economy Action Plan to determine whether future legislation will include Heavy Duty Vehicles and how any future End of Life legislation will affect Heavy Duty Vehicles. Since Volvo Group has an interest in this thesis, we take our final findings regarding Heavy Duty Vehicles and apply them to Volvo Group's specificities, resulting in three recommendations for Volvo Group: developing an effective reverse supply chain, changing its design strategy into a circular one, and implementing a circular business model.

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Keywords: Circular Economy, End-of-Life, Circular Economy Action Plan.

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List of abbreviations :

- BMI - Business Model Innovation.
- BOL - Beginning of Life.
- CBM - Circular Business Model.
- CE - Circular Economy
- CEAP - Circular Economy Action Plan 2020.
- CSR - Corporate Social Responsibility.
- ECHA - European Chemical Agency.
- ELV - End of Life Directive 2000/53/EC.
- EOL - End of Life.
- EU - European Union.
- GHG - Greenhouse Gases.
- HDV - Heavy Duty Vehicle.
- LCA - Life Cycle Assessment.
- MHCV - Medium and Heavy-Duty Commercial Vehicles.
- MOL - Middle of Life.
- OLP - Ordinary Legislative Procedure.
- PLC - Product Life Cycle.

1. Introduction

The concept of Circular Economy (CE) has largely been discussed by academia, industry, and policymakers for a while. It has often been stated that CE creates a "win-win" situation since it solves resource insufficiency, reduces environmental impact, and provides economic advantages for businesses (Wening and Spinler, 2020).

The main objective of CE is preventing waste and it can be applied to all manufacturing industries, including the automotive industry. This study revolves around applying circular activities at the end of life (EOL) phase of a Heavy Duty Vehicle (HDV) as an initial step towards full circularity throughout the lifecycle of a HDV.

The purpose of this chapter is to present the overall content of this report. After an introduction to CE, the HDV industry will be described. Finally, the scope, as well as the objectives and research questions of the study will be presented.

1.1. Circular Economy (CE)

Although CE is a relatively new concept, the concept has developed through a set of established theories, including industrial ecology, natural capitalism, blue economy, and performance economy (Moreno et al., 2016). Some practical aspects of CE can be traced back to the Second World War period, during which resources were short. Therefore, industries were forced to reuse and remanufacture existing products (Lieder and Rashid, 2016).

Despite the burgeoning literature on the concept, there is no widely accepted CE definition (Saidani et al., 2017). The reason for this is that a functional CE requires many actors to interact with one another (Kirchherr, J.,et all , 2017). Moreover, trying to set firm boundaries to the concept CE has proved difficult due to the different perspectives of the different actors. Nevertheless, a widely accepted definition of CE is the one provided by Ellen MacArthur Foundation (2013), according to which:

"A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the

elimination of waste through the superior design of materials, products, systems, and, within this, business models."

Furthermore, according to Ellen MacArthur Foundation (2017), CE is based on three pillars:

- designing out waste and pollution,
- keeping products and materials in use, and
- regenerating the natural system.

CE is often described as a combination of two types of cycles (see figure 1); technical and biological (Burke, Zhang and Wang, 2021). Technical cycle refers to the closed loops within which inorganic material cannot be biodegraded and returned to the biological system. Circularity in this context involves preserving the value of these materials as long as possible by keeping them within the circle. Materials and products are thus kept in use. This may be accomplished through several different processes, such as planned maintenance, reusing, remanufacturing, refurbishing, and recycling. Moreover, a more circular approach, including reuse and remanufacturing, will minimize waste. By doing so, we are preventing the generation of waste and pollution.

Biological cycles, on the other hand, refer to the closed loops within which organic materials are returned to the biological system, thereby conserving energy and providing food. As a result, the natural system is regenerated (Burke, Zhang, and Wang, 2010).

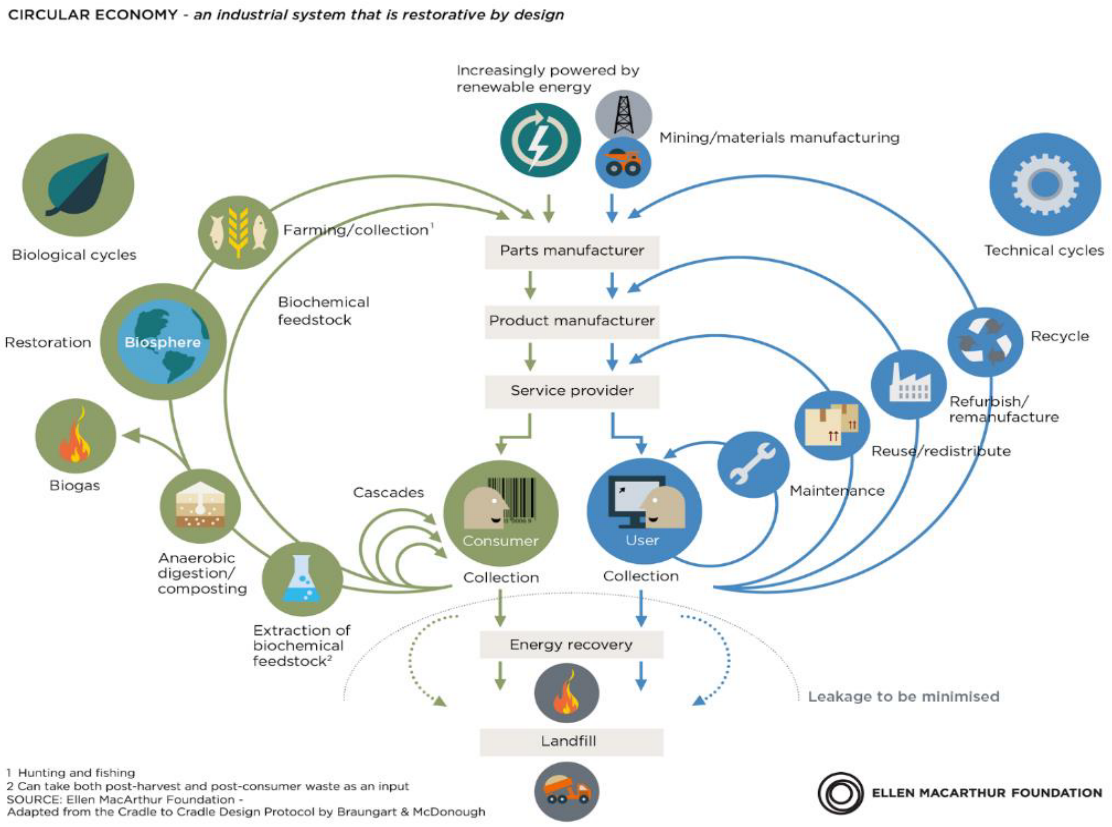

Figure 1: circular economy illustration by Ellen MacArthur Foundation.

1.2. The automotive industry

The automotive industry in the European Union (EU) has been subject to an intensive amount of legislation and regulations throughout the years (European Automobile Manufacturers' Association, 2020). The following figure illustrates regulations applied within the automotive industry in the EU. This list is not exhaustive, but it covers a great variety of regulations which ranges from safety to environmental requirements.

Year	Area	Category	Year	Area	Category
1985	Unleaded petrol	Fuel Directives	2003	Biofuel Directive	Fuel Directives
1992	Euro 1	Euro standard	2005	Euro 4	Euro standards
1993	Sulphur Content of fuels	Other	2005	ELV Type-approval	End-of-Life vehicle Directive

1996	Euro 2	Occupant protection	2005	Front protection systems	Pedestrian protection
1996	Air quality framework directive	other	2006	Emissions from AC	CO2 emissions
1996	Side impact	Occupant protection	2008	Rear impact protection	EuroNCAP
1996	Frontal impact	Occupant protection	2008	Electronic stability, Lane Departure warning etc.	General safety
1997	EuroNCAP establishment	EuroNCAP	2009	Road safety vehicles regulation	Occupant protection
1998	1998 fuel quality Directive	Fuel Directives	2009	Pedestrian collision tests	EuroNCAP
1998	Voluntary CO2 reduction commitment	CO2 emissions	2009	Reduction of CO2 emissions from new passenger cars	CO2 emission
1999	Consumer labeling	CO2 emissions	2009	Tyre labeling & TPMS	CO2 emissions
2000	Euro 3	Euro standards	2009	Euro 5	Euro standards
2000	Monitoring CO2	CO2 emissions	2009	Renewable Energy Directive	Fuel Directives
2000	ELVs	End-of-Life vehicles Directives	2012	Mass and dimensions	N/A
2001	Voluntary agreements on safer car fronts	Pedestrian protection	2013/2014	Amendments to 2009 CO2 regulation	CO2 emissions
2001	Seatbelt reminder	EuroNCAP	2014	Sound and silencing	N/A
2003	Pedestrian protection	Safety	2014	Euro 6	Euro standards
2003	Child protection rating	EuroNCAP			

Table 1 : Regulations within the automotive industry by ACEA.

According to Statista (2021), In 2019, almost 500,000 commercial vehicles were produced in Europe. Over the course of that year, almost 300,000 medium and heavy commercial vehicles were sold in Europe. It is estimated that Europe, including Turkey and Russia, had more than 11,6 million medium and heavy trucks in use in 2019 and a motorized rate of 75 units per thousand people. The automotive industry in the EU generated nearly 1.12 trillion euros in revenues in 2018 and exported 6.6 billion euros, primarily to other European countries. The market for medium and heavy-duty commercial vehicles (MHCV) represents a significant portion of this market.

To facilitate the EU regulatory process, products belonging to the automotive industry are classified into five categories (Directive 2007/46/EC). In particular, categories M and N include vehicles with four wheels which are used for carrying passengers and goods, respectively (Directive 2007/46/EC).

- M_1: Passenger vehicles that have eight additional seats besides the driver and are built for carriage of passengers.
- N_1: Vehicles constructed and designed specifically for the transportation of goods, not exceeding 3.5 tones in mass.
- M_3: Passenger vehicles with more than eight seats in addition to the driver's seat, and with a maximum mass exceeding 5 tones.
- N_2: This category includes vehicles designed and constructed to carry goods and having a maximum mass of over 3,5 tones but not exceeding 12 tones.
- N_3: Vehicles that are designed to carry goods and have a maximum mass of more than 12 tones.

The HDV industry is defined by three subcategories: M_3, N_2, and N_3. This being the case, HDVs are defined as trucks with at least four wheels, used to transport goods weighing more than 3.5 tones or more than 16 tones, representing N_2 and N_3 subcategories respectively. Additionally, HDVs include all vehicles that are used to transport passengers that meet the specifications in the M_3 subcategory. Since HDVs are a wide variety of vehicles in terms of

their performance, number of axles, and height of their chassis among other factors, we use these subcategories to classify them.

1.3. Scope

A critical factor for the success of a CE is the level of engagement from governments and policy makers to develop rules that drive waste flows back into the system, by promoting not only recycling but also remanufacturing and refurbishing for example (Lieder and Rashid, 2016).

Public efforts to promote CE vary across countries. Developed countries like Sweden, Germany, and Japan are continually mentioned in research as examples to follow regarding waste reduction and recycling regulations (Lieder and Rashid, 2016). Despite significant efforts by individual countries, taking initiatives on a regional level is far more beneficial and it has a considerably bigger influence on a global level. This is especially true for a region like the EU, which represents a unique political, economic and legal form of cooperation between 27 countries geographically located close to one another.

According to Ellen MacArthur Foundation (2013), the EU transition towards CE could create 1.8 trillion EUR in economic benefits, 600 mil EUR in cost savings, and a 33% reduction in greenhouse gasses (GHG) emissions related to production for goods consumed only in the EU. Due to the synergy effects, these numbers have been amplified by the collective efforts of all members of the EU. They probably could have been smaller if the initiative had been taken on a national level even though providing the same efforts.

Gusmerotti et al. (2019) indicate that the EU efforts for CE are due to the fact that the amount of natural resources present in the EU is unsatisfactory to satisfy increasing levels of EU demands for products and services and upgrade living standards. He EU consumes roughly eight billion tons of material each year, out of which fifth is imported (Gusmerotti et al., 2019). Thus, our research is confined to the EU on a geographical level, and to the automotive industry subcategories M_3, N_2, and N_3.

1.4. Purpose

It is the intention of this thesis to examine the concept of CE, to determine what legislations are in place regarding this concept, to examine the EOL legislations within the automotive industry, as well as to gain a better understanding of how a possible EOL legislation would affect the HDV industry. Overall, the main purpose of this thesis is to assist Volvo Group in setting targets in order to mitigate the adverse effects of possible EOL legislation on the HDV industry.

1.5. Research questions

Having established the objectives previously mentioned, we developed four research questions whose answers will provide a basis for discussion, ultimately allowing us to attain the objectives. The research questions are the following:

1. What does the concept of Circular Economy mean?
2. What are the current and upcoming rules for circularity in the European Union?
3. What implications can be drawn from the relationship between End-of-Life Directive 2000/53/EC and Circular Economy Action Plan 2020 from the perspective of the Heavy Duty Vehicle industry in the future?
4. What implications would End of Life regulatory requirements have for HDVs?
5. Which targets can help Volvo Group to mitigate with new End of Life regulatory?

2. Data collection

This thesis work is based on an understanding of information on CE and EOL gathered from two categories of documents: scientific articles and EU official publications, including both legal and non-legal texts.

The process of data collection was initially focused on gaining an understanding of CE, combining the academic and the policy and legal perspectives. An EU official publication which was key for this thesis work was the European Circular Economy Action Plan 2020 (CEAP), which will be presented in detail in section 5.

After studying the CEAP, the decision was taken to narrow-down the focus of this thesis work to the EOL. This decision was motivated by two main reasons: firstly, the main criteria discussed on the CE such as reuse, repurpose, remanufacture and recycle would happen at the end of life (EOL) of a product. So, the inclusion and exclusiveness of the EOL procedures can ensure implication of the CE to some extent. Secondly, the European Commission has proposed new legislation on the battery and hazardous substances that covers all the vehicles including the heavy duties, when in the previous similar ones only the light vehicles were included. Moreover, a revision on the EOL legislations is planned to be published in the fourth quarter of 2022. Therefore, there is a major concern for vehicle industry players such as Volvo that how inclusive the upcoming EOL legislation can be and what impacts it would have on their business. To elaborate more on concerns from Volvo, 7 interviews have been conducted to deep dive on the related department of Volvo and their insights on this legislation and CE concept, actions which have been taken by Volvo and what is their future plan (If there is one within their team). The table below illustrates summary of these interviews:

interviewee	Department	responsibility	Insights from meeting
Elinore Axelsson	Group Truck Technology	Director Vehicle Technology & Services	• Introducing sustainability targets of Volvo Group • Explaining Volvo's expectation of this master thesis which is providing CE targets for Volvo Group
Marie Pierre	Group Truck Technology	Manager of the product regulation team	• Explanation of the thesis and its scope • Introduction of Volvo organization overall and regulation department in specific
Kristian Claeson	Group Truck Purchasing	Sustainability manager	• They believed that purchasing has a significant role in implementing circularity and will cooperate in this transition. • Currently, they have no specific guide or circularity requirements for their supplier.

Daniel Stranne And Daniel Björkbacke	Group Truck Technology	Product Planning Manager And Senior Product planner	• They explained how product planning and product design work together • They clarified that the focus of Volvo is on maintenance, remanufacturing and predictive maintenance which they believe are the core principles of circularity but they cannot define their way of working as circular style.
Karin Alenius-Circularity expert in regulation department	Group Truck Technology	Senior Product Regulation Specialist	• Circularity regulation focus: Batteries and waste, Substances and EOL • Volvo's concerns toward these new regulations • Suggestion for HOW to implement circularity
Andreas Gustafsson-	Group Truck Operation	Vice president of Circular Operations & Solutions	• EOL treatments for trucks are limited to after market • They have NO system for taking back trucks at their EOL or information beyond the first owner of trucks. • They see conflict between profit making and extending the lifetime of vehicles. Meanwhile, they view implementing circularity as adding service to Volvo's Business model.
Linea Nilsson-	Group Truck Technology	Senior CMF[1] Designer	• Product design team is trying to make the transition to being circular, especially in the new products. • They want to apply circularity as they have been applying for zero CO2 emission • Their Plan is to become circular by 2026 partially and completely by 2030 • They consider a variety of legislations for making targets such as ,LCA,

[1] Color, Materials, Finish

			Taxonomy, EU directive and Circular Economy Action Plan

Table 2: Summary of interviews

As it is stated in the table 2, Volvo Group is concerned about which targets they should set in order to mitigate the challenges this new legislation would bring along if it is adopted by the European Commission and European Parliament and this was the main outcome of this thesis from their side.

Therefore, discussing the potential extension of upcoming legislation of the EOL and its implication on the heavy-duty industry is the final goal of the thesis which enables identifying targets for Volvo Group in order to mitigate them as well. In order to pursue this goal, the new legislation of batteries and substances and other recent initiatives within the CE has been studied to understand the extension of these regulations. Besides, the current EOL legislation and evaluation of it by the European Commission has been studied. Together with all the mentioned information, an analysis has been made to understand the relation and effects of and a discussion which finalizes the writer point of view of the EOL future legislation and its challenges for the HDVs.

3. Theoretical framework

This chapter presents the theoretical foundations upon which this study is based, concerning the concepts of CE and EOL.

3.1. The concept of Circular Economy

We discuss three fundamental aspects of CE in this subsection. The first aspect is how CE differs from the conventional linear approach. This is followed by a discussion on the similarities and differences relating to sustainability. Lastly, the economic incentives engendered by CE are discussed.

3.1.1. Circular Economy versus Linear Economy

There is a general agreement on the conceptualization of CE as an alternative approach to the linear economy approach, which is widely adopted today (Saidani et al., 2017).

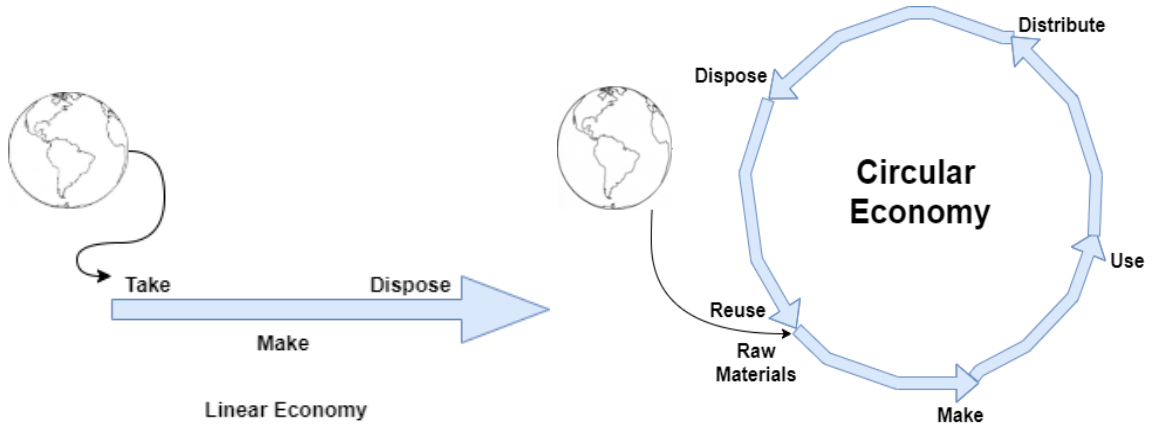

Figure 2: Illustration to distinguish between linear and circular Economy.

As shown in Figure 1, the linear approach is also referred to as the take-make-dispose approach (Burke, Zhang and Wang, 2021). This approach embraces a consumption behavior that got nurtured after the industrial revolution when companies purposefully encouraged people to dispose of their products and purchase new ones (Lieder and Rashid, 2016). Product life cycles were intentionally shortened (i.e. planned obsolescence) to stimulate the stream of new products and increase revenues (Lieder and Rashid, 2016). Although these behaviors were advantageous for economic growth, they had severe consequences on the environment regarding depletion of scarce resources, pollution, and waste generation (Lieder and Rashid, 2016).

Put differently, the resources available on the planet are finite, economic growth will lead to population growth and improving living standards. Hence, the depletion of scarce resources will continue upwards. Therefore, considering an alternative approach to the Linear Economy has become critical (Lieder and Rashid, 2016).

3.1.2. Sustainability and Circular Economy

Sustainability in its wide scope is defined by Dahlin (2015) as following:

Satisfying today's needs without jeopardizing the ability of future generations to satisfy their needs.

Comparatively studying sustainability and circularity has increasingly gained attention among researchers and academics. Therefore, many studies have contributed to the debate concerning differences and similarities between circularity and sustainability. For instance, studies have been carried out on the differences between business models for sustainability and circularity (*Geissdoerfer, M., et al.,2018)*and (Pieroni et al., 2019), and studies on the differences between sustainability and circularity indicators (Rigamonti and Mancini, 2021; Superti et al., 2021).

Overall, sustainability and circularity differ in their ultimate objectives. While sustainability strives to balance social, economic, and environmental aspects, CE focuses on changing the economic order into a more resource-efficient one by closing materials and energy loops. Managing business impacts on people, both positively and negatively, is known as social sustainability, while environmental sustainability aims to ensure that natural resources are conserved in the present as well as in the future, while economic sustainability aims to achieve long-term economic growth without adversely affecting social or environmental aspects. Although commonalities between sustainability and circularity exist, a complete match is not reachable (Mancini and Raggi, 2021).

Sustainability explicitly declares the social aspect as fundamental as the other two aspects. Maximizing one aspect at the expense of another is not acceptable in sustainability. On the other hand, CE does not address social prosperity as one of its main drivers (Pieroni et al., 2019). However, CE might result in benefits on the social level, but it is considered a secondary impact (Pieroni et al., 2019).

According to Geissdoerfer et al. (2018), sustainability-oriented business model innovation (BMI) contains characteristics and objectives beyond those depicted for ordinary BMI, such as sustainability value, pro-active multi-stakeholder management, and long-term perspective. Moreover, a Circular Business Model (CBM) contains additional characteristics and objectives such as slowing, narrowing, and closing resource loops. However, pursuing all these objectives simultaneously could bring complexity, and a need for trade-offs may emerge. Hence, a CBM could exclude sustainability objectives to preserve its circularity character, i.e., a production line that enables circularity while causing a flawed working environment.

Pieroni et al. (2019) depict differences regarding BMI from another perspective. In particular, these authors emphasize that although the main drivers for CE, such as economic growth and resource efficiency, are also primary drivers for sustainability, CE does not consider the social aspect as a primary driver contradicting the sustainability approach in this manner.

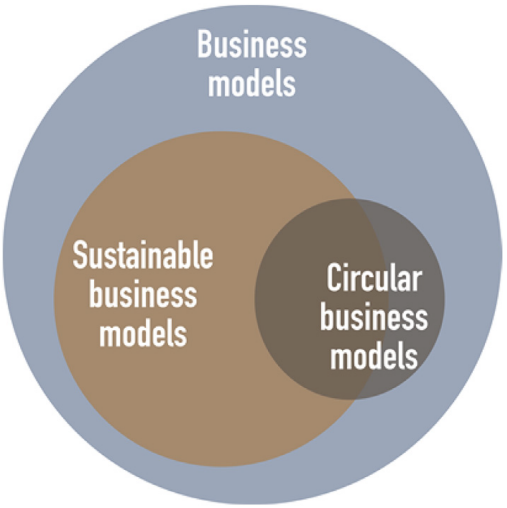

Figure 3 : Visualization of business models differences by Pieroni et al.(2019).

Similarly, several other studies indicated that CE indicators focus more on environmentals aspects, while sustainability indicators are more inclined to social aspects (Superti et al.,2021; Mancini and Raggi, 2021; Rigamonti and Mancini, 2021).

To conclude, CE is considered as complementary and driver to sustainability (Mancini and Raggi, 2021). Therefore, it is important to separate these two concepts and not refer to them as synonyms (Gusmerotti et al., 2019). Although the CE concept is related to the more comprehensive concept of sustainability, relatedness does not imply resemblance. A circular product is not necessarily sustainable and vice versa.

3.1.3. Economic incentives in CE

Argumentative discussion for rationalizing the concept of CE in research often starts with the idea of resource scarcity and environmental impact (Lieder and Rashid, 2016). As a consequence, the critical aspect of economic advantages embedded in CE is often disregarded. According to (Lieder and Rashid, 2016), the economic perspective is a critical building block for a successful transition towards CE as vital elements for the implementation

of CE are in the hands of business decision-makers. Such elements include choosing materials, business models, product design, and supply chain design, which are decided based on cost-output assessment (Lieder and Rashid, 2016).

Lieder and Rashid (2016) propose a framework that incorporates all three perspectives, environmental impact, economic benefits and resource scarcity, to make it easier to outline the interrelated relationships between them (see figure 4). Manufacturers depend on scarce resources to perform their manufacturing operations to gain profits and competitive advantage. Conversely, scarcity of resources leads to price volatility which compromises the manufacturer's competitiveness and profits. During production, manufacturers harm the environment through emissions, landfills, and waste generation. Contrariwise, environmental impact leads to regulations that affect economic benefits gained by manufacturers. Finally, growth in population leads to an increase in resource depletion, which impacts the environment negatively. Similarly, this will increase the speed of waste generation, which makes resources even more scarce. In conclusion, this framework illustrates how CE presents a better approach by simultaneously considering all three perspectives and their respective interrelated relationships.

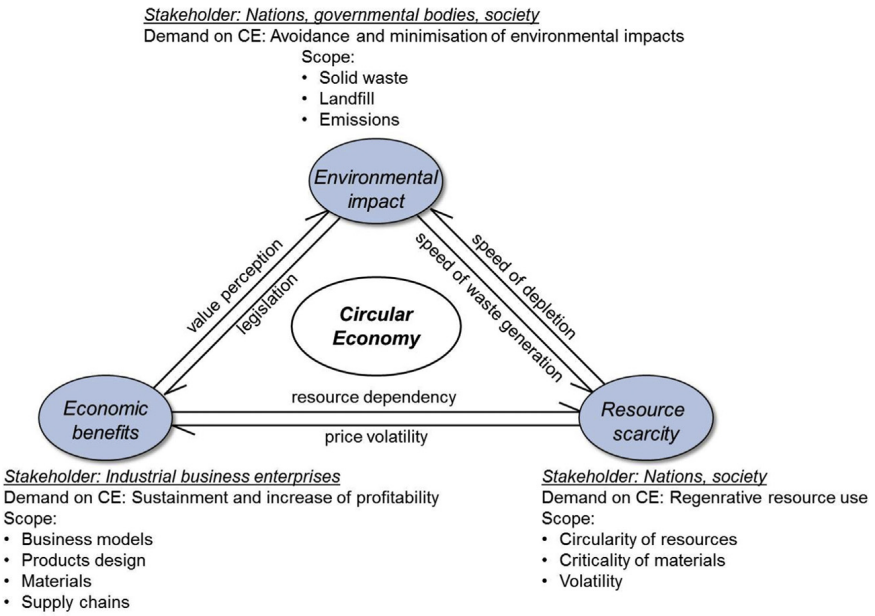

Figure 4 : Visualization of interrelated relationships between the three key drivers of CE by Lieder and Rashid (2016).

3.2. End of Life (EOL)

In this subsection, we will introduce product lifecycle management (PLM) and its relationship with EOL, followed by an extensive discussion of EOL as a concept, especially when placed in the context of the automotive industry (primarily heavy-duty vehicles).

3.2.1. Product Lifecycle Management (PLM)

The concept of PLM refers to the business activity of effectively managing all company's products across their life cycles (Stark, 2020).

According to CIMdata (2002), PLM is defined as:
A strategic business approach that applies a consistent set of business solutions in support of the collaborative creation, management, dissemination, and use of product definition information across an extended enterprise, from concept to end of life, integrating people, processes, business systems and information.

This concept has gained tremendous attention since its emergence in the last decade (Cao et al., 2009). The significance of this approach is that it extends beyond the boundaries of the firm. In PLM, products are managed from the time they are conceptual ideas until they are retired or thrown away by customers (Stark, 2020). Moreover, PLM manages the whole range, from individual parts through the single product to the entire portfolio of products. According to Cao et al. (2009), there is clearly a dichotomy in the emergence of PLM since it has emerged within both academia and the market. PLM offerings have proliferated and diversified in markets with a recent particular focus on IT, whereas academic research has evolved from marketing research to concentration on integrating flows of both material and information throughout the value chain. The ultimate objectives of PLM are reducing product-related costs, increasing products' revenue, and maximizing products' value for both customers and shareholders (Stark, 2020).

PLM is a must in an industrial context to handle the complexity and diversity of a company's products (Stark, 2020). Products differ in the embedded components and production processes. Products get increasingly complex as they contain different industrial components such as hardware, software, electrical, electronic, and chemical. Production processes could

be done by the company itself or by its suppliers. The following table depicts a typical number of components embedded in a set of products to showcase the degree of complexity.

Product	Number of included components
Deodorant	20
Sandwich	30
Shampoo	50
Watch	300
Machine tool	2000
Car	25000
Aircraft	400000

Table 3 : Showcase of the increasing number of included components in complex products.

Initially, PLM was designed as a tool to enable firms to identify successful products from failures (Cao et al., 2009). This, however, is a marketing mindset where product sales are projected in four distinct stages (birth, growth, maturity, and decline) (see figure 5).

Since the late 1970s, new applications of PLM have been developed (Cao et al., 2009). PLMs range in form depending on their intended purpose, which can extend from strategic management and organizational structure to environmental and sustainability objectives. The latter has resulted in widely used techniques such as Life Cycle Assessment (LCA). Stark (2020) asserts that the different aims coexisting within the context of PLM are reflected in the variety of terms and forms used in various PLM approaches. PLM could be viewed from either a user or manufacturer perspective. From the user's perspective, a product's lifecycle consists of five phases: ideation, definition, creation, implementation, and disposal. The product life cycle can also be broken down into five phases as seen from a manufacturer's standpoint: ideation, definition, realization, support, and retirement. Final stages from both perspectives, disposal, and retirement, are called EOL phases. Although we are only interested in the perspective of the user in this thesis, we are focusing on it because the EOL

phase, from the manufacturer's perspective, is the process of ending the production of some products based on declines in sales, whereas from the user's perspective it is the process of disposing of an existing product which is the main subject of this thesis.

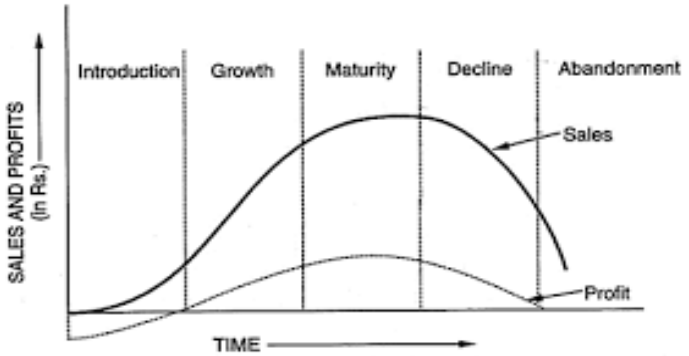

Fig. 6.1. Stages in Product Life Cycle.

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Figure 5 : Product lifecycle by Cao et al. (2009).

The focus of research in the PLM field has shifted towards initiatives that integrate both material and information flows, since this type of integration results in advantages from environment and strategy perspectives. According to Kiritsis et al. (2003) product life cycle is divided into three phases; Beginning of Life (BOL), when product is designed and produced, Middle of Life (MOL) when product is used, serviced, and repaired, and finally EOL when product is discarded by its user and it may be reused, refurbished or recycled. This approach (see figure 6) has considerable importance because it displays the information flows between various phases that are critical in the context of CE. In order to achieve CE, it is necessary to consider all these three phases, including flows between them. Nevertheless, we will focus on the EOL and its relationship to earlier phases. Cao et al. (2009) highlight that this approach aims to solve the problem resulting from the fact that information flows cease after the product is sold, preventing other stakeholders such as the production and design representatives from gaining access to valuable information.

The following figure represents the product lifecycle approach by Kiritsis et al. (2003).

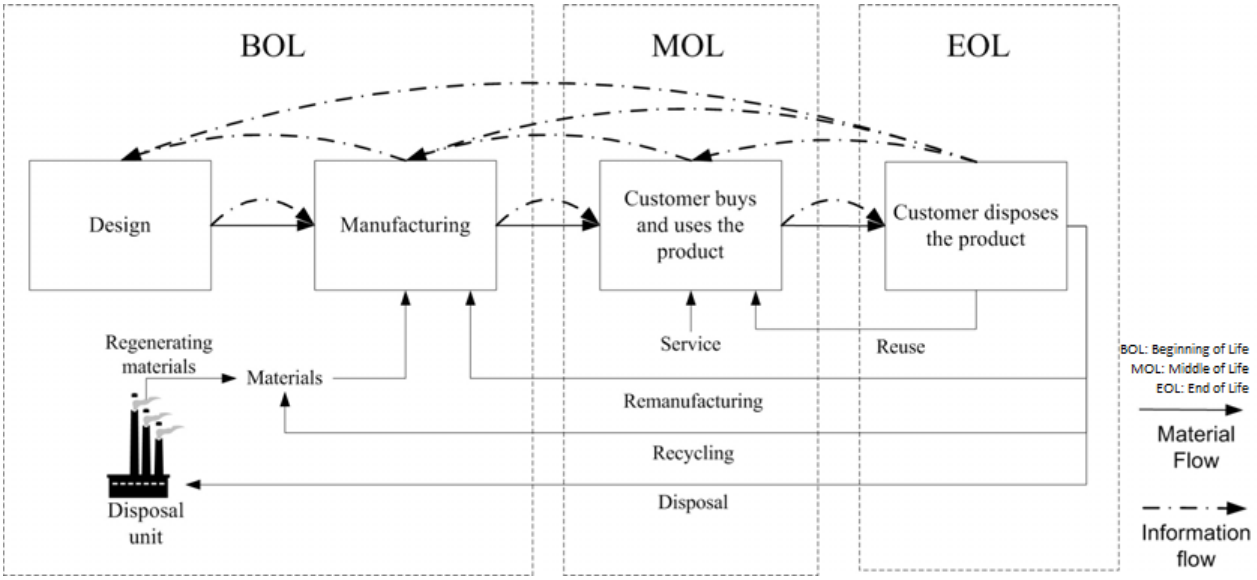

Figure 6 : Product lifecycle divided into three main stages by Kiritsis et al. (2003).

3.2.2. EOL phase

EOL refers to the final stages of the product's lifecycle (Stark, 2020). Whether the EOL is considered from a manufacturer's perspective or a user's perspective, EOL considerations may differ depending on the product in question. As a manufacturer, EOL concerns include discontinuing production and addressing the market needs that the product addresses, which may lead to the development of a new product. A business using the product may have EOL concerns such as how to dispose of the existing product responsibly, how to switch to a different product, and how to ensure that the business disruption will be kept to a minimum.

A new set of regulations has helped bring EOL into the light due to its role in requiring manufacturers to take on responsibility for their products' environmental implications during additional stages of the product life cycle (Toffel, 2003). Up to that point, the majority of manufacturers focused their management efforts on design, procurement, manufacturing, and marketing (BOL). After the sale of a product, there was no further contact with the product, except for after sales services such as maintenance and repairs (MOL). EOL management results in reducing environmental negative impact, resource and energy conservation, and hazardous substances control (Mangold, 2013). As shown in Figure (7), four potential reverse material flows exist from EOL to either BOL or MOL: reuse, remanufacturing, recycling, or disposal.

- Reuse: A process where products or components are used again without any extra work (Mangold, 2013).
- Remanufacturing: The process of restoring used products to like-new conditions using energy and materials recovered from primary production at a low additional cost, thereby reducing product prices (Remanufacturing).
- Recycle: A process of dismantling products into pieces to reuse material and recover resources (Mangold, 2013).
- Landfill: A process of disposing materials, components or entire products in landfills (Mangold, 2013).

These reverse material flows represent different strategies for EOL which have to pass through a logic order in which the reuse choice is prioritized over all other choices, followed in order by remanufacture and recycle, and then, if all other options are unreasonable, landfill. Therefore, each product or component is assessed in order to determine whether it is still feasible for reuse, if not, then it is automatically routed to the second option, remanufacture. If that is deemed impossible due to various reasons such as complexity in disassembly, then the viability of recycling will be assessed. If that is deemed infeasible, then landfill is the choice. The following figure illustrates this logic.

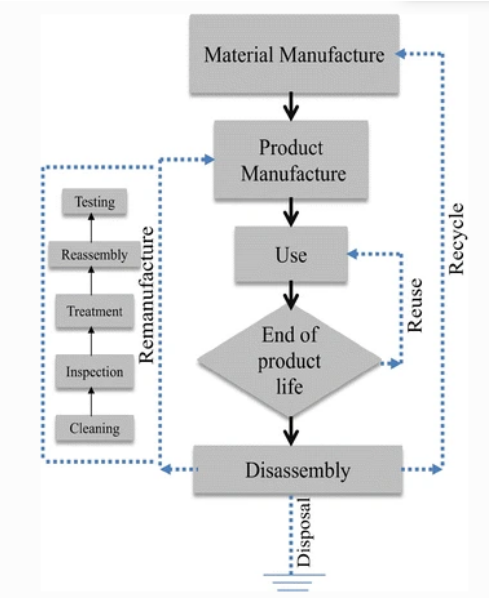

Figure 7 : Visualization of reverse material flows by Mangold (2013).

4. EU decision-making

In the European Union, various legislative procedures are used to introduce new EU laws. The European Commission, the European Parliament and the Council of the EU are the three main institutions involved in EU decision-making. The Parliament represents the interests of the EU citizens, while the Council of the EU represents the national interests of the EU member states. Instead, the European Commission is the voice of the EU's overall interests.

The most common legislative procedure is the so-called Ordinary Legislative Procedure (OLP). In the OLP, the Parliament and the Council of the EU are co-legislators. In other words, both the Parliament and the Council of the EU scrutinize legislative proposals and jointly adopt legislations. For this reason, the OLP is also known as the co-decision procedure. In addition to the OLP, Article 289 of the Treaty on the Functioning of the European Union (TFEU) refers to special legislative procedures (SLP). In the case of SLP, the Council is the sole legislator. Nevertheless, the Parliament needs to give its consent or be consulted for a legislative proposal to be approved. SLP are not detailed in the TFEU. In fact, rules governing SLP are defined on an ad-hoc basis.

In the context of the OLP, the European Commission is assigned almost exclusively the right to formulate legislative proposals. The European Commission plays an essential role in driving forward the EU integration process. Therefore, it is assumed that legislative proposals formulated by the European Commission would maintain a neutral character and be based on the general interests of the EU as a whole. The European Commission can also formulate legislative proposals based on invitations received from the EU Parliament, the EU Council, or EU citizens either by collecting one million EU citizens signatures in seven different member states or by submitting a petition to the EU Parliament.

As illustrated in the next sub-paragraph, the ordinary legislative procedure may become quite complex and require a long period of time to be completed. To speed up the process and make sure that relevant issues are addressed in a timely manner, so-called trialogues have become quite common. Trialogues are informal meetings between representatives of the European Commission, the European Parliament and the European Council organized to facilitate negotiations concerning the content of a legislative proposal and eventually lead to an

agreement. Statistics show that trialogues have substantially contributed to speed up the process of adoption of legislative proposals (Monte & Smialowski, 2021).

4.1. The ordinary legislative procedure (OLP)

The OLP starts with the simultaneous submission of a legislative proposal from the European Commission to the Parliament and the Council of the EU. Although the Parliament and the Council of the EU examine the European Commission's proposal in parallel, the Parliament acts first, communicating to the Council of the EU whether it would approve the European Commission's proposal as it is or propose amendments. This is generally referred to as the Parliament's first reading position.

The Council will then decide whether to accept the European Commission's proposal as amended by the Parliament or propose amendments. If the Council accepts the Parliament's first reading position, the ordinary legislative procedure ends with the adoption of the legislative proposal. If the Council proposes to introduce changes, the so-called Council's first reading position is sent to the Parliament for a second reading.

The Parliament has three to four months to examine the Council's first reading position. There are four possible outcomes for the Parliament's second reading: 1) the Parliament approves the Council's first reading as it is and the legislative procedure ends with the adoption of the proposal as modified by the Council; 2) the Parliament fails to take a decision within the time limit and therefore the legislative procedure ends with the adoption of the proposal as amended by the Council in its first reading; 3) the Parliament rejects the Council's first reading position and the legislative procedure ends with no approved text; 4) the Parliament decides to amend the Council's first reading position.

In this last scenario the Parliament's second reading position is sent to the Council for a second reading. The Council has three to four months to examine the Parliament's second reading position, having also received the European Commission's position on the Parliament's proposed amendments. If the Council approves the Parliament's second reading position, the legislative procedure ends with the adoption of the proposal, as amended. If the

Council rejects the Parliament's second reading position, the so-called Conciliation Committee is set up.

The Conciliation Committee is composed of an equal number of Parliament and Council representatives, and it has six to eight weeks to decide on a joint text based on the Parliament's and Council's second reading positions. If the Conciliation Committee does not agree on a joint text, the proposal falls, and the procedure is ended. If the Conciliation Committee approves a joint text, the text is forwarded to the Parliament and the Council for a third reading.

At this last stage, the Parliament and the Council have six to eight weeks to decide, and they cannot modify the text. The procedure ends with the adoption of the proposal if the text is jointly approved. Otherwise, the proposal falls and the procedure is ended. The European Commission can decide to start a new legislative procedure with a new proposal (Hardacre and Andrien , 2015).

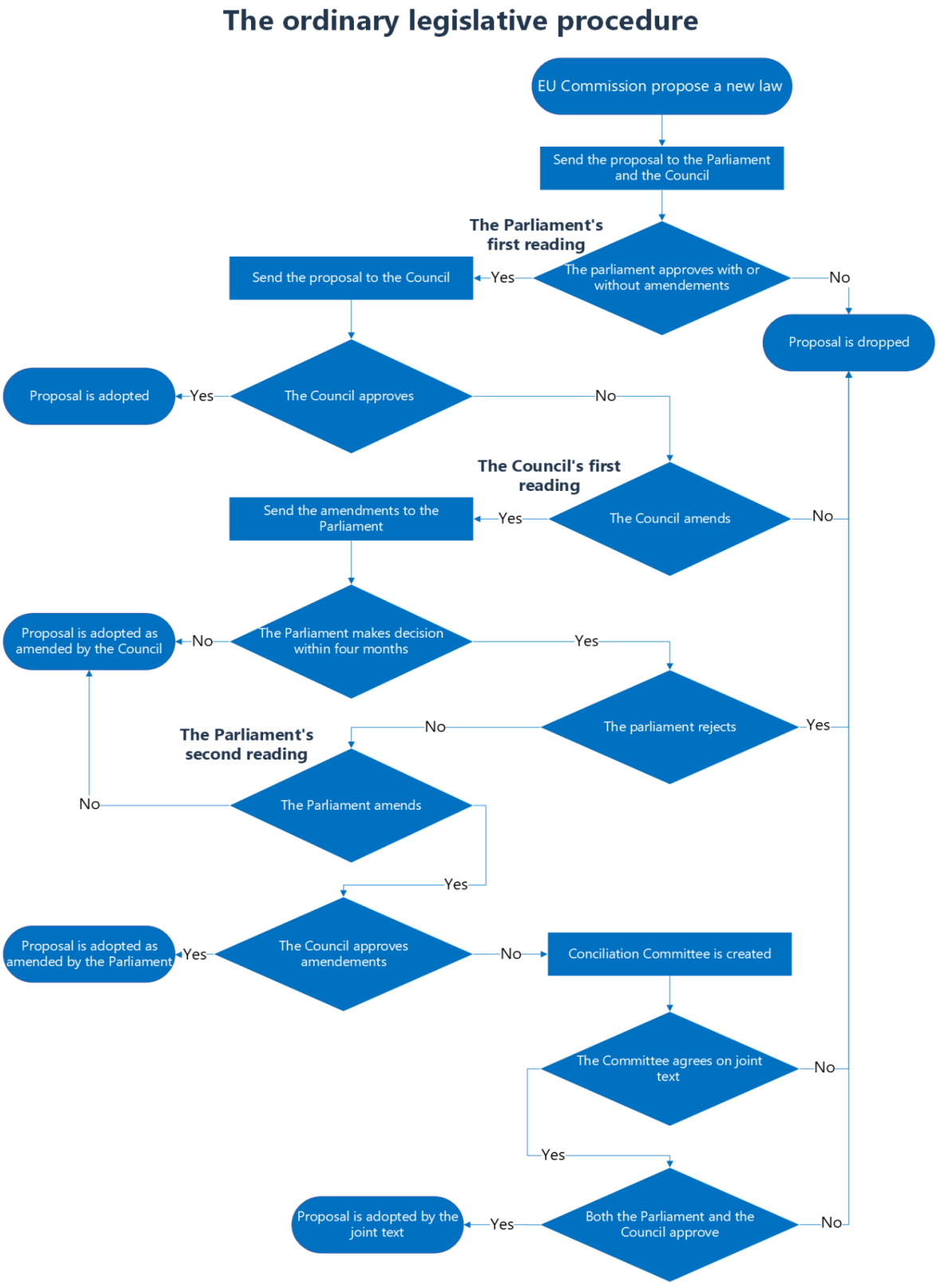

Figure 8 : A flowchart representing the workflow of the ordinary legislative procedure.

4.2. Different types of EU laws

Legislative acts adopted as a result of a legislative procedure can take the form of a regulation, a directive, or a decision. Regulations are the most pervasive form of all EU legal instruments as they apply directly and uniformly to all EU member states, without the need to be transposed into national laws. Contrary to regulations, directives need to be transposed into national legislation. Directives are considered less intrusive of national legal systems as they are used to set goals to be achieved by the EU member states which are given the freedom to set their preferred way to achieve such goals. Similar to regulations, decisions are also directly applicable. Nevertheless, decisions clearly specify whom they are addressed to. The targeted group can include private or legal persons, or a specific group of EU member states (European Commission, 2019b).

4.3 Action plans: key areas to be legislated upon

An action plan is a detailed plan outlining the steps that should be taken in order to solve a problem, reach a goal, or improve regulation (Pact of Amsterdam, 2016). An action plan is supposed to provide a list of important data regarding the resources needed, the steps involved, and the priorities of those steps in order to achieve its goals (Team, 2019).

Upon the approval of an action plan, the European Commission proposes new initiatives based on the steps outlined in the action plan. Clearly, new initiatives have been proposed by the European Commission in response to the CEAP, adopted in 2020 (European Commission, 2020). Similarly, the new initiative for sustainable products as well as the new initiative for taking actions to reduce the impact of microplastics on the environment were developed with reference to the considerations mentioned in the action plan (European Commission, 2020).

Consequently, an action plan may be regarded as a road map for future legislation within the EU. A number of action plans have already been adopted by the EU other than the CEAP 2020, such as "5G action plan" and "Innovation for a sustainable Future - The Eco-innovation Action Plan", which were published in 2016 and 2011 respectively. (Mejia, 2019)

5. Circular Economy Action Plan (CEAP)

Based on the European Commission's conclusion, linear economies cannot function indefinitely in a world where resources are becoming scarcer, as raw materials are used to make products that are eventually discarded as waste (Santander, 2021). As a result, the European Commission suggests that we transition from a linear economy to a CE as a means of keeping up with economic growth and protecting the environment at the same time (European Commission, 2020e). In this context, the concept of sustainable growth is implied. Several legislative initiatives have been implemented in the EU over the last decade to promote sustainable growth. By enacting legislation that ensures circular production, Lin (2020) argues that sustainable growth can be achieved.

To facilitate the transition from linear to Circular Economy, the EU adopted its first CEAP in 2015. This document covers the entire product cycle from production to consumption. It included 54 actions which are categorized into 6 main areas: resource efficiency, transformative innovation for moving towards a Circular Economy, sustainable usage of material, sustainable production, and promoting green consumption (Skawińska & Zalewski, 2018). In 2019, the European commission reported that actions mentioned within this plan have been included in the EU legislations, thus this action plan has reached its purpose (*European Commission,2020a).*

A new Circular Economy action plan, which is the latest action plan on this topic, was adopted in 2020. The actions proposed in the plan are being implemented through new proposals that have been presented by the European Commission. A new framework for making products more sustainable is presented in chapter one of CEAP. Following that, in the second chapter, seven key value chains are defined that have scarce resources or play a critical role in applying CE. Furthermore, the third chapter discusses ways to produce less waste with a minimum number of toxic components, prohibits the export of waste to countries outside the EU, and creates a profitable market within the European Union for second-hand materials. As a final point, it establishes circularity for regions and cities as well as a global approach for achieving circularity on a worldwide scale. (European Commission, 2020b).

The CE cannot be achieved without the active participation of both customers and producers according to the latest action plan. This would be accomplished by providing more comprehensive information to public buyers and extending the responsibilities of producers regarding their production, choice of materials, final goods, and EOL of their products.

5.1. A sustainable product policy framework

A sustainable framework for product policies is illustrated in chapter one of the CEAP. This framework identifies various requirements that products should meet in order to contribute to ensuring a climate-neutral, resource-efficient, and CE, and thereby reducing waste. Specifically, CEAP urges the European Commission to propose a sustainable product policy legislative initiative with the goal of expanding the eco-design Directive beyond energy-related products and enhancing durability, reusability, upgradeability, and reparability of products, defining hazardous chemicals in products, and raising the utility usage of energy and resources. Additionally, it intends to promote recycling with a higher quality, reduce carbon footprint, and increase information transparency through digital product passports.

5.2. Key-value chains

As outlined in the CEAP 2020, there are six key value chains that have serious environmental impacts and result in sustainability concerns. Accordingly, this action plan illustrates the importance of immediate, inclusive actions as a means of overcoming these challenges. These actions are an integral part of the Sustainable Framework discussed in the previous section. Among them are electronics and ICT, battery vehicles, textiles, packaging, plastics, constructions and buildings, food, water, and nutrition. Even so, since this thesis is clearly focused on the Heavy-Duty vehicles industry, we will focus on only related value chains in the following sections, namely plastics and batteries.

5.2.1. Plastics

Recently, the public has become increasingly concerned about the growing number of plastics and the dangers they pose to the environment. According to the CEAP 2020, mandatory requirements for recycled content and measures to reduce the amount of waste in key products such as packaging, construction materials, and vehicles are suggested. Furthermore,

it has been suggested that measures be taken in order to reduce the amount of microplastic. Despite this, no specific requirements have been outlined in the CEAP for recycling plastic. Only additional funds and resources will be made available for related activities and to promote the Circular Plastics Alliance (CPA), which has been making contributions this way since February 2019.

CPA aims to inspire the European market to recycle 10 million plastics by 2025 and use them to produce new products. In order to achieve this goal, 3.4 million additional tons of plastic should be recycled in addition to what was recycled in 2020. Therefore, the collection and sorting capacity of plastic wastes should be increased to 4.2 million tons by 2025, as well as the recycling capacity to at least 2.8 million tons. A total of € 7.6 billion to € 9.1 billion is required to complete this project. Furthermore, according to CPA, 26 of the EU's most popular products are responsible for 60 percent of plastic waste. These products must increase their recycling rate over 80% in order to achieve the alliance's objectives. Generally, these products can be classified into five categories: agriculture, construction, automotive, and electrical and electronics (European Commission, n.d.b). In 2019, 1,500,000 plastic samples were collected from the automotive industry, 350,000 of them were sorted for recycling, and 43 % of them were actually recycled.

An additional concern in the CEAP is the spread of microplastics into the environment and particularly into the oceans. The term microplastics refers to plastic pieces smaller than 5 mm. These plastics are intentionally added to a variety of products, including tyres, textiles, and paint. Nevertheless, this is not the only limitation associated with the production of microplastics. Unintentional production of this type of plastic occurs during production or use, where it disperses and becomes one of the major sources of pollution in seawater (N. Evangeliou et al., 2020). In this context, one recommendation of the CEAP is to put restrictions on microplastics by establishing standards of unintentional plastics and requiring labeling or certificates of their contents on source products, especially tyres and textiles. Moreover, the European Chemical Agency proposes to restrain the intentional addition of microplastic to products through the implementation of this action plan (European Commission, 2021b). Finally, the action plan mentions a lack of study on the risks of spreading microplastics in the environment, especially in drinking water and food which human health is directly dependent on.

5.3.2 Batteries and vehicles

The CEAP emphasizes the importance of circular and sustainable vehicle batteries as an imperative component of future mobility. There is a strong sense that new legislation is needed on batteries to promote circularity and ensure sustainability of upcoming batteries in the electromobility sector. In order to address this need, the European Commission promises to develop a comprehensive regulatory framework.

A comprehensive regulatory framework on batteries would set requirements for the recycling of batteries' contents, as well as provide assurances that valuable materials can be recovered. Measures could also be taken to increase the collection rate of batteries as well as their recycling rate. It is also important to note that all batteries are included in this new framework, despite the fact that only batteries used in vehicles under 3.5 tons were included in the previous directive. Therefore, the HDV industry needs to pay more attention to this issue. Additionally, the CEAP recommends that transparency and sustainability be applied to all aspects of battery production and treatment, as well as the recommended legislation. Therefore, all producers are obligated to disclose their carbon footprint, ethical raw material sourcing, and supplier information to their customers and industry. Furthermore, all actors would be required to improve their battery treatment procedures, such as reusing, repurposing, and recycling (*European Commission ,n.d.a)*.

New battery legislation is likely to emphasize revising EOL legislations on the basis of the CEAP. This revision is designed to promote a CBM by simplifying EOL treatments for batteries. Furthermore, mandatory recycling contents will be established for certain battery components along with more efficient recycling procedures. Besides, the European Commission will devise the most effective measures in relation to waste oil collection and environmentally friendly treatment. According to CEAP, the revision will be available by the end of 2020.

5.3. Empowering consumers and extension of producer’s responsibilities

Consumer participation in choosing sustainable products is a cornerstone of CE policies. This is also true of producers' commitment to accepting an extension of their responsibilities

during the transition to a Circular Economy. To encourage consumer participation in the transition to a circular economy, the CEAP suggests revising EU consumer laws (European Commission, 2022c). The purpose of this is to ensure that consumers receive relevant and reliable information about products at the point of sale. This includes the lifespan of the product and the availability of maintenance services at the point of sale. Additionally, the European Commission will provide assurances against greenwashing and premature obsolescence, as well as mandate minimum requirements for sustainability, including labels, logos, and information tools (European Commission, 2022c).

Empowering customers extends beyond providing them with information in the CEAP. Consumers have the right to repair at every level, including spare parts, under the "Right for Repair" concept.

The extension of the producer's responsibility is an additional strategy for promoting CE in the EU in order to reduce waste (Campbell‐Johnston et al., 2021). Thomas Lindhqvist introduced the concept of Extended Producer Responsibility (EPR) in 1990 and included a shift of responsibility from governments to producers in terms of reducing environmental impacts from the design and manufacturing phases until the EOL phase (European Commission, 2014).

EPR is considered one of the most effective means of achieving the CEAP's waste reduction targets. It is therefore expected that companies will be required to submit data about the environmental footprint of their products and organizations in accordance with the CEAP. The European Commission will test the integration of these methods into the EU Ecolabel with respect to durability, recycling, and recycled content more systematically. It is pertinent to note that one of the most critical areas for vehicles is the EOL of products, which is discussed in section 3.2.2. In order to prevent waste and promote a higher amount of high-quality recycling as well as more environmentally friendly waste streams, CEAP calls for a revision to EU legislation on End-of-Life of vehicle and battery vehicles.

6. Results

6.1. Changes in legislation as a Result of the Circular Economy action plan 2020.

Even though an action plan describes in detail changes that need to be made, it is not a legally binding document. All key players in the market are concerned whether or not it is possible to implement legislation based on the action plan. Hopefully, they may be able to gain valuable insights from the legislations already implemented or proposed by the CEAP. Thus, we will now present all of the related policies and proposals within the automotive industry that were conducted in accordance with the CEAP in this section. However, a database of all legislations and initiatives based on the CEAP is provided in Annex 1.

6.1.1. Eco-design regulation

The EU Commission has adopted a new regulation of eco-design for sustainable products in response to the suggested strategy of sustainable product policy framework outlined in the CEAP.

In March 2022, a proposal was presented for a new eco-design and Energy Labeling Working Plan 2020-2024. The aim of this proposal is to increase the material efficiency specially for energy related products,expand the energy related products which will be studied and continue the Product Registry for Energy Labeling under the European existing program. Moreover, it will aim to apply the Circular Economy Action Plan requirements on reparability, recyclability, enhancing end-of-life disassembly and reuse.

6.1.2. New initiative for microplastic issue

Following the publication of the CEAP, several legislative proposals have been made by the European Commission based upon the suggested actions on key value chains. Specifically, in order to address the concern arising from the plastic value chain within the CEAP related to microplastics, the European Commission adopted a proposal on 29th November 2021 to provide measures to reduce the unintentional release of microplastics from tyres, textiles, and plastic pellets. Specifically, this initiative proposes measures for the EOL phase, as changing the source of microplastics is virtually impossible. The European Commission considers that these measures should also be complemented by extending producers' responsibilities in order

to achieve a more effective outcome (European Commission, 2021b). It is advantageous to examine the specific measures stated in this initiative for tyres, since this study focuses on the HDV industry. In the first place, it is imperative that the tyres are designed in an eco-design manner with the possible use of new materials that will comply with the upcoming European Commission abrasion standards. Furthermore, the European Commission intends to promote an investigation of retreaded tyres and the relationship between microplastic emissions and vehicle condition and type (including maintenance, quality of the roads, and driving behavior, including autonomous and human driving), as well as to fill in knowledge gaps. Lastly, the European Commission plans to increase the number of green infrastructures that contribute to the depollution of the environment by microplastics. It is expected that this initiative will be adopted in the fourth quarter of 2022 (European Commission, 2022b).

6.1.3. New battery vehicle regulation

There were two major reasons for requiring a revision of the CE action plan 2020 in relation to vehicle batteries. There are two reasons: the environmental impact of production, use, and EOL treatment of vehicles' batteries, and the benefits for the business. Environmental regulation is primarily concerned with battery design and treatment. The proposed regulation calls for battery design that extends its lifespan, makes it easy to remove and replace, and that customer should not be charged for this procedure. A battery treatment process is of significant importance because it contains a number of toxic substances, such as lead, acid, lithium, nickel, and cobalt, which have the potential to damage the environment and human health severely if they do not receive appropriate treatment (Barnes, 2022).

Further, the listed toxic ingredients are classified as scarce and expensive materials. For instance, Lithium is one of the primary ingredients in EV batteries that faces a monopoly for supplying it as most of the world's Lithium supply comes from Argentina, Bolivia, and Chile (Dubois, 2018). As a result, the price of lithium is rising so recovering it represents a significant financial gain. There is, however, a similar issue with cobalt, another essential component of EV batteries. According to McKinsey Global Institute, cobalt will face a shortage by 2025 (Fien, 2018). For this reason, reusing, recycling, or repurposing batteries with effective collection and treatment rates are the most effective strategies to deal with the supply issue and guarantee the future production of these batteries.

A current legislative framework for achieving the environmental and economic benefits mentioned above is the battery Directive 2006/66/EC. It has already proposed a number of recycling policies and measures to develop the collection and recycling of batteries within the EU. Additionally, it has addressed the issue of replacing non-rechargeable batteries with rechargeable ones whenever they are available. Transparency has been stressed in this directive in which it sets requirements for the carbon footprint of battery manufacturing, the ethical sourcing of raw materials, and the facilitation of reusing, repurposing, and recycling. Based on the evaluation and impact assessment of the batteries Directive 2006, there was a divergence in methods and measurements across regions, which did not yield the desired outcomes. Additionally, the CEAP identified a number of issues that are not addressed in this directive, suggesting that it needs to be revised. Thus, a new battery regulation (with annexes) has been proposed by the European Commission on 10 December 2020, in accordance with the CEAP.

With the new proposed battery regulation, EU market players will be required to comply with mandatory requirements, including restraining the use of hazardous substances, limiting the carbon footprint, extending battery lifetimes and ensuring battery labels are provided for all batteries they sell (i.e. portable batteries, automotive batteries, electric vehicle batteries, and industrial batteries).Moreover, by this regulation, batteries should be collected and receive proper treatment and get second lives as repurposing from industrial batteries to use in other means. This is called the EOL of batteries and what needs to be done with every other component of the vehicle in the EOL phase of the vehicle (European Commission, 2019a). All the requirements proposed in this regulation are provided in the appendix.

6.2. Comparing End of Life Directive 2000/53/EC with Circular Economy Action Plan 2020

Considering that the CEAP serves as a projection of what will be required in order to facilitate a transition towards a CE. Throughout the CEAP, the importance of the EOL phase is emphasized. First of all, the sustainable product policy framework advocates the extension of the eco-design directive into the domain of design for circularity, which directly impacts EOL procedures in a positive and significant way. It also emphasizes the critical role the EOL

phase plays in the issue of plastics, and specifically microplastics. As the automotive industry including the HDV industry expands towards more electric vehicles, the circularity of batteries is becoming increasingly important for the future of mobility. Consequently, the battery would represent the main and most valuable component of the HDV. This would make it necessary to devote more attention to the EOL phase when future regulations may place more pressure on it. Having said that, EOL regulations will have a substantial impact on the entire automotive industry, including HDV, especially when it is heavily mentioned in the CEAP. It is therefore necessary to take a closer look at the EOL directives that already exist, which is the End-of-Life Directive 2000/53/EC (ELV). Even though HDVs are not a part of this directive, it may provide us with some insight into the general nature of EOL legislations.

6.2.1. An overview of ELV's requirements

In summary, the following requirements are set forth in the ELV (Directive 2000/53/EC):

- During design and production, vehicles should be designed and manufactured to achieve quantifiable goals in relation to reuse, recycling, and recovery.
- A general prohibition on hazardous substances, like lead, cadmium, mercury, and hexavalent chromium, only applies when their use is unavoidable.
- Putting in place systems for collection, treatment, and recovery of EOL vehicles.
- Standardization of components and materials through common codes facilitating the classification of these materials as waste.
- It must be possible to access information regarding the design and the EOL process.
- Communicating effectively with consumers in order to shape their attitudes and behaviors.
- Final consumers will not be charged for returning an EOL vehicle.

6.2.2. A PLM approach in the context of ELV

Since September 2000, ELV has been in effect by Directive 2000/53 which was triggered by two factors, namely a huge amount of waste generated by EOL vehicles, which was estimated during the time of the directive to be almost 9 million tons of waste, and a need to harmonize different measures taken across the EU by various member states regarding the disposal of EOL vehicle waste. It is significant to note that although this directive focuses on the EOL

phase of the vehicle lifecycle, it addresses issues related to earlier phases; BOL and MOL, highlighting the importance of adopting PLM approach. Basically, the goal of the directive is to prevent or limit the generation of waste from EOL vehicles by adopting circular strategies such as reuse, recycling or recovery, which cannot be achieved by focusing only on the EOL phase.

Throughout the ELV, different aspects of the connections between EOL and BOL are discussed.
First, the emphasis on the prevention of using hazardous substances during the conception phase of the vehicle. According to ELV, hazardous substances such as lead, mercury, cadmium, and hexavalent chromium were set limits so as to reduce their emission into the environment, as well as to facilitate recycling. As a result, disposing of hazardous waste is avoided. Moreover, CEAP aligns with ELV on cooperation of all industry sections to develop efficient systems for tracking and gathering information on substances with chronic effects or substances which pose technical problems in recovery operations. Thus, it would be possible to identify and measure them under the sustainable product policy framework with the European Chemical Agency (ECHA). This would enable us to take action based on policies related to materials, including high concern substances. The European Commission will also examine ways to make EU agencies and scientific institutions more effective in implementing 'one substance - one assessment' policy and to improve chemical management transparency as well as to prioritize actions with greater transparency.
Meanwhile, the regulatory framework will need to quickly respond to the scientific evidence regarding the hazards posed by endocrine disruptors, hazardous chemicals in products, including imported products, and combination effects of chemicals. Following the directive, several amendments were adopted concerning the use of hazardous substances, all of which aimed to prohibit the use of lead, mercury, cadmium, and hexavalent chromium in components and materials used to manufacture vehicles that were put on the market after July 1, 2003. Nevertheless, this was exempted when its uses were unavoidable, such exemption needs to be reconsidered in light of recent technical and scientific advances that may render avoiding them conceivable.

Secondly, the directive emphasizes the BOL phase by requiring the integration of design and production on new vehicles with requirements of dismantling, reuse, and recycling of EOL vehicles. Accordingly, all member states should establish a framework for ensuring a coherent

approach among national and EU approaches in the design of EOL vehicles. This means that both manufacturers and importers should ensure that the designs for vehicles meet the requirements of waste treatment. In order to achieve this objective, the European Commission will encourage the preparation of European standards for type-approval legislation to be amended in order to accomplish this goal. According to the CEAP, for example, there is a point about 'sustainable products' that specifies that all products should be designed in a circular manner so that Circular Economies can be realized and how recovery can happen more efficiently. Finally, recyclability is emphasized as a major element of waste prevention. Therefore, the directive emphasizes the importance of promoting recyclability and improving recycling methods, with a particular focus on plastics.

In a similar manner to addressing the connections between BOL and EOL, the directive offers a particular emphasis on links between MOL and EOL by emphasizing the reusing as well as reducing the usage of materials as compared to recycling. At the same time, the producer is held responsible by this directive, which insists on EOL concerns as well. Furthermore, an overall measurement to ensure all actors in this industry are cooperating in the collection, treatment, and recovery of EOL vehicles is critical.

On the basis of this directive, an attestation of destruction should be provided for the de-registration of EOL vehicles. Member states without a de-registration system should devise a system for the provision of attestation of destruction to the appropriate treatment facility when a driver turns over an EOL vehicle. If customer participation is not included in these regulations, the results will not be satisfactory. To involve customers in the process, they should be informed of all new directives and new decisions so that they can adjust their behavior and attitudes accordingly. An authorized treatment facility should be able to accept a vehicle from the last owner without any costs and the vehicle should possess no or a negative market value so that there is no incentive to keep it out of the system.

Nevertheless, ELV does not only cover treatment. It also mentions waste management. In accordance with this directive, waste generation should be reduced as much as possible, and it should be possible to collect and discard end-of-life vehicles without negatively impacting the environment. Reusing, recovering, and recycling are key components of a CE. Among the topics covered in the review of the CEAP is waste management, and it is intended to limit the export of waste containing harmful elements to third countries. As a result of this review, the

waste will be treated domestically within the EU, thereby preventing the diversion of the waste abroad. As part of the European Commission's mandate to strengthen waste tracking in the EU, it will support the tracking of illegal exports and illegal trafficking in order to strengthen the control over waste shipments. The focus of this review will be on problematic waste streams and waste operations.

Moreover, ELV was amended by Directive 2018/849, which stipulates a series of additional requirements to help evaluate the compliance of member states more efficiently. Moreover, it focuses on standardizing the process of EOL to facilitate the reuse and recovery of components. There will, however, be revisions to ELV pertaining to EOL vehicles, as well as directive 2005/64/EC regarding type approvals concerning reusability, disposal, and recycling.

Furthermore, it is anticipated that the two directives will be combined into one document covering the entire life cycle of products in the automotive industry. Additionally, the upcoming revision will include issues related to EOL treatment, and rules regarding mandatory recycled content for components will be considered, as well as improving the recycling efficiency. The legislation, as well as an impact assessment, are expected to be published in the fourth quarter of 2022.

6.3. Flaws of End-of-Life Directive 2000/53/EC and Circular Economy action plan 2020

Considering we have reviewed ELV as a means of gaining a general understanding of EOL regulations, and since the CEAP identifies EOL at various points. A review of ELV's compliance with the CEAP is necessary. This will help clarify what has been missed in the ELV and will probably result in the future regulation of the EOL for vehicles that might include HDVs as well. Upon evaluating ELV in relation to the CEAP, it is evident that ELV does not adequately satisfy the requirements for implementing the CE in the automotive industry in terms of coherence and effectiveness. Using the evaluation of this directive published by the European Commission in March 2021, all of these areas will be discussed in detail in this subsection.

6.3.1. Coherency with EU circularity strategy

The evaluation of ELV contributions to the most critical aspect of the CEAP, which is facilitating the transition towards a Circular Economy, has found that ELV is relatively inconsistent with the objectives of the European Green Deal and the CEAP. Clearly, ELV does not adequately address key aspects of the transition to a Circular Economy.

Furthermore, ELV does not include any specific terms that would have a significant impact. The treatment of plastics and glass, for example, requires special consideration, and general targets of reuse/recycling and reuse/recovery by weight do not guarantee proper treatment for these materials. Since ELV was introduced more than 20 years ago, it has been unable to address the challenges and conditions of the current market, despite the amendments made in 2018. Electronic devices and plastics are more frequently used today than 20 years ago.

Moreover, inadequately general strategies for increasing the amount of recycled material within vehicles are another example of insufficient coherence between the circularity approach of the EU and the ELV. Increasing the use of recycled materials in vehicles is considered a key component of the CEAP. The EU Plastic Strategy 2018 and the growing use of plastics by the automotive industry make this an even more pressing issue. Therefore, it is imperative to require a minimum amount of recycled material in vehicles, but ELV only encourages vehicle manufacturers to increase the use of recycled materials. To put it another way, ELV does not contain any specific and technical legal requirements relating to the minimum content of recycled materials. Although many pioneering companies such as Volkswagen, Mercedes, and Volvo Group and Volvo Cars have taken voluntary steps to increase recycling materials in their new vehicles, the absence of legal requirements results in an insignificant improvement.

6.3.2. Effectiveness of the ELV

A two-pronged approach will be used to evaluate the effectiveness of ELV: first, whether ELV's targets have been met; second, whether ELV's scope extends to all vehicles.

6.3.2.1. Effectiveness of the ELV regarding to its targets

To reduce the amount of waste produced, this directive aims to enhance the treatment of EOL vehicles from dismantling to reusing, recovering, and recycling during the design and production phases. However, given that there is no obligation to make any changes to meet the target at these phases, and only encouragement is provided to manufacturers, little progress is being observed in the design or production of new vehicles to facilitate more circular and easier EOL treatment. This has resulted in a relatively small reduction in waste production.

Moreover, ELV lacks specific reusing targets. It mandates producers to have (85% by an average weight per vehicle and year reuse and/or recycle) and reuse and/or recovery of ELVs (95% by an average weight per vehicle and year). Therefore, the share of reuse varies considerably for all EU member states and, in some cases, this ambiguous target has resulted in reuse being neglected by producers, they mostly decide to recover or recycle over reusing since the directive has no obligation of doing both treatment methods and the decision is up to the producer.

6.3.2.2. Effectiveness of the ELV regarding to its scope

In general, ELV applies to all vehicles having a weight of less than 3.5 tons. In view of this, a significant number of vehicles (such as trucks, motorcycles, trailers and semi-trailers, road tractors, special-purpose vehicles, buses, etc.) are excluded from the scope of the directive. Therefore, the EOL of these vehicles is unregulated by any legislation from the EU, resulting in a major sustainability problem and blocking the transition to a CE for approximately 45 million vehicles, which account for a significant portion of the automobile industry.

As a result, a significant number of these vehicles (with a weight less than 3.5 tons) are exported to countries outside the EU and do not reach these treatment facilities, despite ELV stating that all of the above vehicles should be transferred to authorized treatment facilities. The vehicles in question are referred to as "missing vehicles", which is one of the most serious shortcomings of this directive.

As a general rule, this directive prohibits the export of vehicles that have reached their EOL to countries outside the European Union. It is, however, difficult to distinguish between a used car that is a waste and a used car that is not a waste because there is no particular obligation

for exporting used cars. There is no legally binding guidance available for this purpose within the EU that can set certain criteria in order to make it feasible. Due to this, a significant number of used cars that would be considered waste within the EU are exported to African countries such as Libya, Nigeria and Ghana as useful used cars. Vehicles in such conditions are not in compliance with environmental standards such as Euro 4/IV emissions standards, and they can pose an environmental risk due to the leakage of hazardous liquids and substances for public health and those who perform treatment activities for them. Generally, these vehicles are not able to reach the EU's treatment facilities, resulting in the permanent loss of their useful components and materials.

7. Analysis and discussion

The purpose of this chapter is to examine the potential changes to the ELV and the potential form of its revision. Following that, the challenges, and drivers of these changes for the key actors, especially HDV, will be discussed. Finally, potential targets for the Volvo group in order to mitigate the impact of the future ELV legislation will be discussed.

7.1. Potential changes of the ELV

According to the evaluation of EU commission staff for the ELV, it has an ineffective definition of scope, lacks specific design requirements and targets for material treatments, and misses extension of producer’s responsibilities (European Commission, 2021a). Therefore, the potential changes of the ELV are expected to be in such areas. In this section, an analysis of these problems and possible ways of resolving them is investigated.

7.1.1. Change of the scope

As it was mentioned in section 7.2.1.2, due to limited scope of ELV, a large number of vehicles are not included at all. However, the need for transition to a CE can be efficiently fulfilled only by implementing this transition in all parts of the vehicle industry. Therefore, other types of vehicles such as HDVs will potentially be added to the revision of this Directive.

It is estimated that HDVs powered by internal combustion engines (ICEs) account for a quarter of all road transport-related CO2 emissions in the EU (Reducing CO2 emissions from heavy-duty vehicles). This disproportionate share of emissions can largely be attributed to the high mileage of HDVs. As EOL climate impacts are relatively low, they have received less attention throughout the entire life cycle (MUNIR, 2021). However, the EOL phase of HDV is of considerable significance in terms of recyclability, even though immediate emissions are not so significant (Broadbent, 2016). However, the potential ELV of HDVs has certain circumstances which are different from other vehicles and cannot be easily added to the current ELV. As a matter of fact, the European Automobile Manufacturers Association (ACEA) has stated in its discussion of the possibility of including HDVs in ELV that the situation for HDVs is completely different and does not meet the requirements for comparison with passenger cars. The HDV did not have EOL legislation until now for the following reasons:

- Due to their complexity such as special product structure, large number of components and complex design, HDVs cannot be smoothly standardized as is the case with passenger cars.
- Within the ecosystem of a truck, there are three different actors: the manufacturer, the body maker, and the customer. Chassis are manufactured by manufacturers, and the bodies are customized based on the specifications of the customer. Thus, it is difficult to meet recycling goals for vehicles under the ELV due to the amount of post-manufacturer modifications.
- HDVs' volume in the EU is relatively small compared to passenger cars' volume (425,150 across the entire EU in 2018 to 15,2 million passenger cars).
- HDVs are valuable products, and their embedded components inherit this value as well. Thus, they already have a strong presence on the second-hand market. They are reused for one or more times in other regions after being used in the EU for their first lifetime. Although this increases reusability, it also creates a high risk of not receiving proper handling at their EOL. Together with low volumes, this explains the low number of trucks which are scrapped in the EU.
- Unlike passenger cars, HDVs have entirely different performance requirements. They are expected to operate 24 hours a day under extremely tough conditions. Therefore, they must be seen to be durable and reliable in the eyes of prospective customers.

> Hence, manufacturers provide their customers with special maintenance contracts to protect them from expensive repair costs. These contracts in turn provide remanufacturing operations with a steady stream of input to maximize their profitability. Furthermore, in order to meet high performance requirements, it is hard to avoid using heavy metals from a strictly technical perspective. HDV manufacturers, however, have voluntarily ceased using heavy metals when it has proven economically and technically feasible to do so.

Throughout the time HDVs were not included in ELV, but manufacturers have willingly adopted some environmental requirements regarding recycling in their operations according to ELV. everyone. Still, this is not adequate for making the whole HDV industry circular. In other words, Due to the high percentage of steel and metal in these products, they get recycled, but not under specific conditions that make the process sustainable, environmentally friendly, and with no hazardous substance leakage. Furthermore, in the absence of a legislation which makes them stay within the EU, HDVs have active second-hand markets outside of the EU in countries with less strict environmental regulations. Therefore, there is a strong need for specific legislation for identifying EOL HDVs and an obligation for the key players to accept expansion of their responsibility in taking them back and use their treated parts in their new production or aftermarket.

7.1.2. Transition to eco-design for a circular vehicle industry

It is important to note that ELV does not comply with the requirements of the Working Plan on Eco-design and Energy Labeling 2020-2024 and the Sustainable Product Policy Framework outlined within the CEAP. A major coherency issue of this directive is that they are not aligned, which in turn will lead to reduced improvement. Therefore, a possible modification to this directive would be to align it with eco-design and require key players to comply with the new requirements. Yet, it remains to be seen to what extent the key players will have to change their designs and how it will impact their new vehicles. Making an eco-design policy consistent with the ELV may result in designing vehicles in such a way that they are easily disassembled and enable EOL treatment procedures to be conducted.

A decline in complex design can be expected, which will pose a challenge to key players, especially HDV manufacturers. HDVs are currently designed in a complex manner to operate

in specific circumstances, and it is challenging to find a solution that meets both eco-design and operational requirements.

7.1.3. Set of clear targets and specific requirements for all treatments

Due to the absence of specific treatment requirements, ELV cannot have a significant impact on the results. The only targets established are the general targets for reuse/recycling and reuse/recovery by weight and these targets do not account for certain materials, including plastics, electronic components, and glass. When assessing the rate of treatment by weight, these parts weigh lightly and do not have a significant impact. Some of them, such as plastics and glasses, are not economically attractive to treat (since a virgin component is cheaper than a recycled component). As a result, manufacturers would not be inclined to treat them in the absence of a legal requirement. Additionally, some of them, such as plastics, pose a serious environmental risk and are already subject to more legislation. In light of this, the forthcoming ELV needs to specify targets and requirements for such materials. In order to meet these recycling and other treatment targets for such materials and components, it is necessary to ensure that vehicles are disassembled extensively before shredding. A requirement to remove vehicle parts before shredding is not included in ELV. It is likely that more detailed requirements are to be expected in this regard.

Additionally, reusing needs to have more specific and clear goals in order to eliminate the variation in reuse rates between EU member states. The use of recycled content in the aftermarket and new vehicles is a must for the transition to CE since it reduces waste and utilizes usage of existing resources. ELV does not include a minimum amount of recycled content in vehicles. A revision of the approach to encourage recycling will be needed in this revision.

7.1.4. Solving “missing vehicle” problem

It is apparent from the evaluation of ELV that a major obstacle to effective implementation of the directive is the large number of vehicles that are shipped outside of the EU or to foreign countries with less stringent laws and are lost forever. There are loopholes in this directive, as stated in the previous chapter, such as the absence of a specific guideline to distinguish EOL vehicles from used vehicles, and the dysfunction of the reporting system which allows EOL

vehicles to be exported. Some EU member states have put in place policies to track and monitor the shipment of their used vehicles, for example in the Netherlands and Ireland. However, this is not enough to ensure that an acceptable share of the EOL vehicles are reported and undergo proper treatment rather than being shipped out of the EU. In such a case, the Circular Economy concept would not be implemented because closing the industry's loop, one of the most important principles of the CE, is impossible. Moreover, the extension of the producer's responsibility would be in jeopardy.

To tackle this problem, a legally binding guide is needed. This guide would distinguish EOL vehicles from used vehicles and would be implemented throughout the entire EU. It is important that this guide is customized for each vehicle based on its type and functionality. By doing this, there would be no room for self-judgment of the condition of a vehicle, which is based on each individual characteristic. Moreover, the guide should be accompanied by strong regulations prohibiting the shipment of EOL vehicles outside of the EU or even to countries in Eastern Europe which lack proper treatment facilities. These policies align with the CEAP strategy for reducing waste shipment from the EU. Based on the CEAP, there is a revision to the EU waste shipment regulation that will support changes in the ELV as well.

7.1.5. Potential form of revision of the ELV

Since we have discussed the potential changes of the ELV, we think it needs to be more specific, have clear objectives, and all EU member countries should follow the same path to bring about the required changes. Therefore, It could be assumed that the upcoming revision will be in the form of a regulation**.**

7.2. Main challenges and drivers of HDV key player in adopting with the ELV revision

Adoption to the ELV revision can bring some challenges for the producers because of the EPR and opportunities at the same time. Collecting the End-of-Life products through a reverse supply chain and applying circular design are challenges which HDV producers would face. However, there are drivers which help them overcome the challenges and its costs such as the opportunity of having new revenue streams by applying a new business model ,a

new alternative source for raw material and strength of their brand image. In this section, these challenges and drivers will be explained.

7.2.1. Challenges of HDV key players in adapting to the ELV revision

7.2.1.1. Creating a reverse supply chain

Reverse supply chains refer to the process of returning products to vendors, suppliers, and retailers (Lorena, 2021). It is the process of collecting and classifying goods, materials, and components in order to have EOL treatments such as reuse, refurbishment, recycling, and remanufacturing (Ellen MacArthur Foundation, n.d.). However, creating such a supply chain for EOL vehicles is difficult and costly due to a wide geographical dispersion, lack of infrastructure for collection, and low returns. (Raymond, 2019).

One of the pioneers HDV manufacturers is Volvo Group, it has six remanufacturing plants, most of which are located in the EU and in America (Volvo Group, n.d.). Only one facility was built in India in 2015 and none in other Asian countries. Consequently, a maximum percentage of EOL trucks or their components cannot be treated around the world, not even in the EU (Volvo Group, n.d.). The number of plants (Only 6 plants in the whole world) and their capacity are much less than that which is required to meet the future EOL regulation (Volvo Group, n.d.). Nevertheless, expanding this capacity will result in a high cost since all collection costs are on the producer.

To operate a reverse supply chain, sorting all the HDVs returned to the company is another challenge. Volvo, for example, is experienced in collecting old trucks, disassembling them and remanufacturing them, but their system is not capable of handling such a large number with their existing human and non-human resources. In addition, the Volvo Group's remanufacturing facility is intended only for limited components such as engines, filters, gearboxes, and rear axles. It will be a challenge for Volvo to design the same programs to meet the requirements of future EOL regulation, in which the focus will be on a wider range of components and parts. Finally, the extent of EOL treatment is limited to remanufacturing, whereas Volvo will need to extend it to reuse, refurbishing, and repurposing as well.

7.2.1.2. Circular design

In circular design, products are designed in a way that allows for multiple lifecycles (Bakker & Balkenende, n.d.). For example, products are designed in such a way that they can be disassembled easily, and every component can be replaced and has a chance to be treated (Bakker & Balkenende, n.d.). By managing complexity, producers can achieve circular design.

It is even more challenging for HDV manufacturers to adapt to this change in design, since their products must work in tough conditions requiring complex designs and high-performance standards. Therefore, maintaining a balance between complex designs and circular designs while improving durability, reusability, upgradability, and reparability is a challenge for HDV manufacturers. In Volvo trucks, for example, which are highly recyclable and designed for remanufacturing in many components, some parts, such as multi-material or small electrical parts, are hardly dismantled or reusable, and in cases where they could be dismantled, it is often associated with some damage to them (Saidani et al., 2018).

7.2.2. Drivers of HDV key players in adopting with the ELV revision

7.2.2.1. New business model

In light of the trend towards electric vehicles within the automotive industry, electric vehicles have a simpler powertrain, with approximately 20 moving parts as opposed to 2000 in conventional vehicles powered solely by internal combustion engines (Schartau and Indino, 2021). Consequently, components such as brakes are less likely to be damaged, resulting in fewer maintenance requirements. Thus, aftermarket services generate much lower revenue than conventional vehicles. A change in business model that creates an additional revenue stream is therefore desirable for vehicle manufacturers. A CE approach in the automotive industry is a powerful driver for vehicle manufacturers in general, including HDVs, since the CE can create a new revenue stream through the addition of EOL treatments, which defines a new business model, " Product as Service ".

7.2.2.2. Alternative resources for raw materials

Lithium and cobalt, two materials mentioned in subsection 7.1.3, are in a supply crisis and will face an even more challenging situation in the future due to the increased transition to electric vehicles from combustion engines. However, this supply issue is not limited to these

materials as there is a shortage of raw materials such as steel (coderman, 2021) and aluminum (anuradha, 2022) as well as glass (KING COUNTY WINDOW & GLASS, n.d.). among the top ten most commonly used materials in vehicles (Webteam, 2019). Creating a new source for such materials can be a long-term solution for vehicle manufacturers to prevent future supply crises. Having the ability to reuse existing materials multiple times by maximizing the collection of EOL vehicles and implementing thorough EOL treatments provides vehicle manufacturers with an incentive to step into the CE transition.

7.2.2.3. Strengthen brand image

The brand image refers to the perception and impression customers have of a brand. This concept is extremely important since it makes a brand more appealing to existing customers and attracts new ones as well (Juneja, 2019). Moreover, Corporate Social Responsibility (CSR) can strengthen the brand image of a firm. It refers to a brand that perceives itself as responsible for the impact that it has on all aspects of society, such as economic, social, and environmental issues (Fernando, 2022). In turn, being sustainable and implying circularity, which reduces a brand's destructive environmental and social impacts can improve CSR, resulting in a positive brand image. Hence, HDV key players who view sustainability as one of their fundamental competitive advantages, such as Volvo Group, can benefit significantly from being sustainable and circular. In the case of Volvo Group, this can be even more relevant, since their code of conduct contains sustainability targets that include climate, resources, and people (Volvo Group, n.d.b) that can all benefit from a CE and proper EOL procedures.

The potential form of this revision of ELV, as stated in subsection 8.1.3, would be a regulation that all companies in this industry must adhere to. As a result, manufacturers who take action in advance in order to comply with these regulations can benefit from having more time in comparison to their competitors, resulting in a smoother transition period. It will enable them to become known as pioneers of becoming circular, which could also provide a competitive advantage in terms of branding.

7.3. Potential targets for implementing circularity and mitigating future EOL regulation

To comply with the potential upcoming regulation of EOL, companies need to develop a plan, and in order to do so they need relative targets. In this section, some examples from the automotive industry have been illustrated which can be a guide for HDV manufacturers for creating such targets.

7.3.1. An examples from automotive industry

Tyson (2016) maintains that benchmarks are always useful when setting targets for a business in order to be realistic and to establish what is considered normal in a particular market or industry. If circularity goals are to be developed for Volvo Group, a competitor within the HDV industry who has provided similar targets should serve as the benchmark. Due to the fact that the ELV only developed targets for vehicles with a weight less than 3.5 tones, our benchmarks can be automotive manufacturers who have set targets in accordance with this directive. Volvo Cars' circularity targets are outlined in the following section

7.3.1.1. Volvo Cars circularity targets

According to Volvo Cars, they plan to increase the percentage of recycled material used in their production. It is expected that by 2025, these new products will contain 25% recycled plastic or bio-based plastic, 40% recycled aluminum, and 25% recycled steel. Furthermore, Volvo Cars are also aiming to transition to circular design (Volvo Group, n.d.a). The company is investigating the possibility of modifying the design of the new models of its products to facilitate easy dismantling and recycling. As part of their efforts to create more circular processes and solutions, they have also begun to build a reverse supply chain in conjunction with their partners. Last but not least, they see the need to find a way to enable better customer, supplier, and user engagement in this transition process. (Volvo Cars, n.d)

7.3.2. Potential targets for Volvo Group

The final research question of this thesis has been identifying targets for Volvo in order to mitigate with new End of Life regulations. In this section, three targets which have been conducted for Volvo Group for this purpose will be introduced.

7.3.2.1. Create a reverse supply chain

Creating a reverse supply chain is the most fundamental objective that Volvo Group must pursue. In the absence of an effective reverse supply chain, closing the loop will be nearly impossible. Presently, Volvo Group receives used parts and EOL HDVs through dealers and prepares them for remanufacturing and recycling. For them to be able to scale up this process, they need to establish additional partnerships with dealers around the world, not only in their countries of presence. This will enable them to collect the maximum amount of their discontinued products. Additionally, there should be more facilities constructed for EOL treatment, such as expanding treatment plants and developing treatment plans that can be used for reusing, repurposing, refurbishing and such.

Accordingly, one might question why they should proceed around the world for dealers and accept additional costs. Despite the fact that the European Commission is likely to enact regulations prohibiting the export of EOL vehicles outside the EU and extending producers' responsibility, there are a large number of EOL Volvo products all around the world that may qualify for the collection process. Additionally, the upcoming regulations will take some time to be fully implemented and Volvo must act sooner rather than later to be a pioneer in the transition to a Circular Economy. The export of EOL HDVs would be prohibited as previously mentioned but used HDVs that are not considered obsolete would still be exported to other countries and their last destination may not be the same as their initial destination. It is therefore essential to have a reliable reverse supply chain to collect them.

Further, Volvo Group's current facilities for EOL treatment are significantly limited geographically and methodologically (Volvo Group, n.d.b). Therefore, the current state of Volvo group treatment plants is insufficient to meet the requirements of a substantial number of already existing EOL HDVs worldwide because treatment plants are few in number (only six) and mostly located in the EU and the United States. However, the final destination of EOL vehicles is not always the EU or the United States. According to an evaluation of the ELV, the majority of these products are exported to African countries. Considering this, it is imperative that these plants be constructed in these countries. Aside from this, remanufacturing and recycling are the only treatment options for EOL parts, such as engines, gearboxes, etc. Thus, in order to comply with potential upcoming EOL regulation, new treatment methods are needed, such as reusing, refurbishing and repurposing. In addition, the focus of these treatments should be expanded to other parts of a HDV such as electronic

devices, plastics, and glasses.

As a final step, encouraging customers to bring their EOL vehicles rather than selling them to other destinations is crucial to scaling up the process. Several strategies exist to increase customer attraction, such as offering bounces or upgrading old parts for a low fee.

7.3.2.2. Moving towards Circular design

Since HDVs are required to work under difficult conditions, they have complex designs that result in a difficult dismantling process. The majority of HDV parts are not designed to be disassembled for the purpose of replacing a few broken parts. It may result in damage to those parts, and, in some cases, it may not even be possible. In order to achieve a circular design, Volvo Group needs to balance the complexity of the design to ensure its proper function with the simplicity of the design to facilitate its ultimate dismantling. Moreover, it is important to increase the use of recycled materials in the manufacture of new HDVs. As a means of achieving these targets, alignment with the eco-design guide from the EU and the one which is expected to be published shortly can be helpful.

7.3.2.3. A change of the current business model

It is necessary to make a change in the business model in order to ensure the achievement of all stated targets. Considering the emphasis on the treatment of EOL HDVs, which is a service, Volvo Group's business model needs to change in order to accommodate the combination of manufacturing and services. Therefore, changing Volvo's business model is one of the foremost targets that will result in the transition to a circular model for HDV producers.

8. Conclusion

One of the major areas of focus of our study was the EOL phase and its regulatory framework. Taking into consideration CE's fundamental idea of closing the loop, we started at the end. EOL plays a significant role in CE implementation since it has a significant impact on the previous phases, BOL and MOL in the PLC (see figure). Since our thesis scope is limited to the HDV industry, we have shifted our attention to ELV as it is the only directive addressing the EOL phase within the automotive industry. Although HDVs are not included in

ELV and represent a relatively small percentage compared to passenger cars, four factors made it worthwhile to explore them further; the attention received by one of the key players, which is Volvo Group, the voluntary circular activities adopted within the HDV industry, the already existing active second-hand market for HDVs, and the rapid pace of developments in the CE regulatory framework within the EU, which is our geographical focus.

The main purpose of this thesis is to assist Volvo Group in defining the goals it needs to pursue to mitigate any potential negative effects that would be caused by any EOL legislation upon the HDV industry. The following figure explains the path we take to answer these questions represented in our research questions.

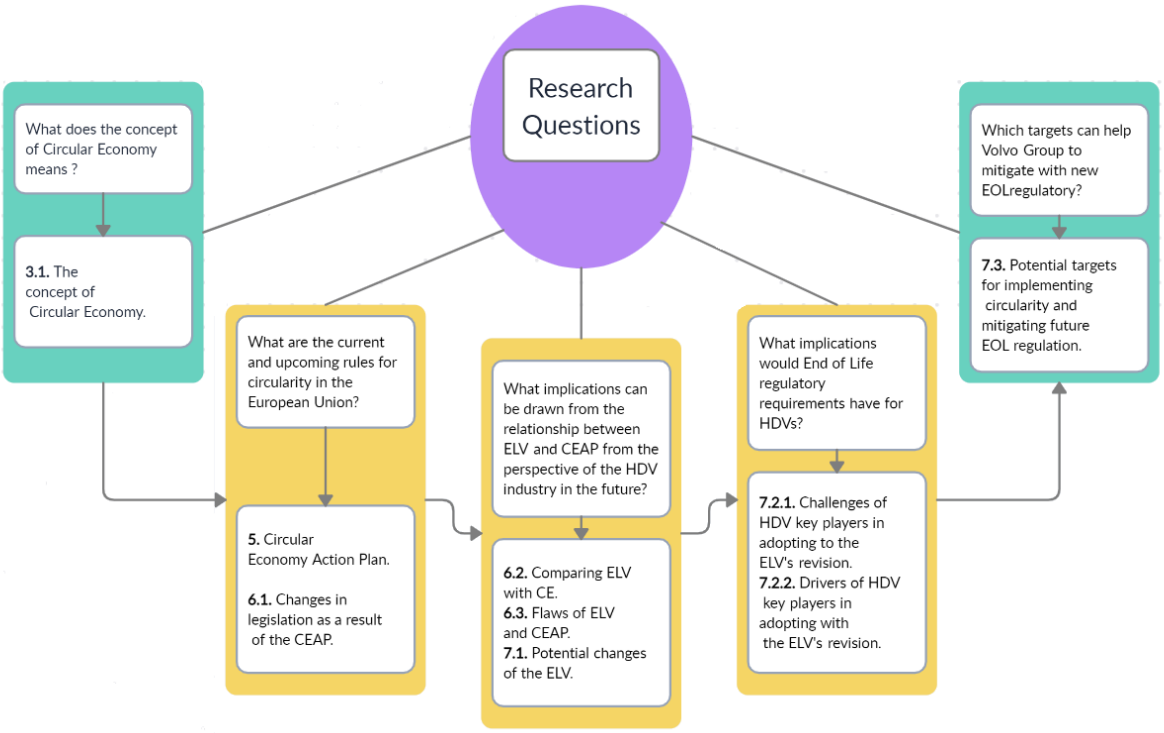

Figure 9: Outline of the thesis

Taking the journey back from the beginning enabled us to fulfill our purpose. We began by looking into the concept of CE. Through every step, we were gaining a deeper understanding of the concept. We found that CE and sustainability are not synonymous as they are currently being used. As a result of our research, we discovered numerous studies highlighting their differences, and during one of our interviews at Volvo Group, we were informed that these two concepts are frequently used interchangeably. Differentiating these two influences the path to be taken in terms of the business model. CBMs and sustainable business models share

some characteristics, but they are not identical. Further, a sustainable product is not necessarily circular, and vice versa. Finally, economic incentives represent one of the main drivers of the CE, which explains the voluntary circular activities within the HDV industry, as well as Volvo Group's attention to the issue without enacting legislation.

Exploring the unknown in a complex decision-making process such as in the EU has not been easy. Throughout history, action plans have played an influential role in imposing a variety of new legislation proposals. We therefore identified CEAP as the one to examine closely in order to gain a better understanding of how CE and EOL would evolve in the future. As we have shown in our study, CEAP has contributed to changes in some legislation, such as eco-design regulation and new battery vehicle regulation. As a result of examining the relationship between CEAP and ELV, a revision of ELV in the form of a regulation could be proposed. The lack of effectiveness in the ELV's scope and targets, along with the indications within CEAP, will likely result in a revision of the ELV in the future that will include the HDV industry. Accordingly, HDV producers are urged to develop a plan to counter the effects of the potential revision of ELV if they wish to operate within the EU. It is anticipated that the ELV's potential revision will require producers to develop a collection system for HDVs at EOL in addition to taking specific measures based on the percentages of each treatment type that would be specified in the regulation. Moreover, A circular design of new products will be required from players in the HDV industry. A circular design is easier to disassemble and allows EOL treatment to be operated smoothly. Although ELV's potential revision would create challenges for the HDV industry, it would, however, provide various attractive economic incentives to motivate the transition to CE, including the potential for additional revenue streams through adoption of a service-oriented business model, cost savings associated with the acquisition of circular raw materials, and improved brand recognition.

To overcome these obstacles and enhance Volvo Group's competitive advantage, we propose three targets for it to pursue. Create an effective reverse supply chain, alter its design strategy into a circular one, and finally implement a CBM.

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Appendix :New Measures of the new battery regulation

This regulation offers 13 measures as related areas which need better regulations and all of them are defined based on an impact assessment of battery directive 2006 ,the analysis from the evaluation of the Batteries Directive, feedback from the public consultation ,supporting studies, and legislations such as the Green Deal.Afterwards, for each of these measures four potential solutions are offered which from 1 to four the level of ambitionary íncreases. In other words,The first option is to keep the Batteries Directive, which mostly covers the EOL stage of batteries, and leaves other areas unchained. This option is with zero level of ambition and acts on the safe zone. However, the other three options are pro to go beyond the Battery Directive But with different rates of severity. The second option has a medium level of ambition which means offering solutions still based on the Batteries Directive and raises the level of ambition moderately. This option suggests providing information and minimum requirements as a criterion for placing batteries on the EU market for the initial phases in the value chain which there is currently no EU legislation.

The third option has a higher level of ambition with a more drastically changing plan but with consideration of technical feasibility .Finally, The 4th offers a solution with a dramatic level of ambition and actions which are ahead of the existing regulatory framework and available technologies. The European Commission prefers to pursue a way which is a combination of option two and option three which is most effective and realistic.These measures are introduced below accompanied with their potential solutions.

1.1. Classification and definition:

This measure is intended for the need of differentiating different types of batteries (portable batteries from EV batteries) in terms of technology and supply.Option 2 for this measure is categorizing electric vehicle batteries with the limit of 5kg weight. Fortunately, all stakeholders have agreed on this solution. However, introducing a set of new methodologies for collection rates of batteries is proposed as option three which is pending a review clause.

1.2. Second-life of industrial batteries

Option 2 for this measure is to consider used batteries as waste at the end of their life (except for reuse).So, all battery treatments such as repurposing would be defined as a waste treatment which result in increasing extra costs for permits that are needed to deal with hazardous waste. . In contradiction, option 3 does not consider batteries as wastes at their end of first life and therefore has less administrative costs**.** Therefore**,** Option 3 is most profitable but the European Commission concluded that a combination of Option 2 and Option 3 which would check the state of health of batteries to identify those which need to be sent for repurposing or remanufacturing from ones which are entitled to be reused.

1.3. **Collection rate for portable batteries**

As portable batteries are not used in vehicles, this measure is out of the scope of this thesis.

1.4. Collection rate for automotive and industrial batteries

Option 2 for this measure offers building a new reporting system for automotive and industrial batteries. This way no economic or administrative cost would apply to the business actors in this industry and only the collection rate of battery waste will be increased.Hence this option is preferred by the European Commission.

1.5. Recycling efficiency and recovery of materials

Recycling efficiency is one of the major issues in battery treatment. option 2 puts targets for 2025 based on the feasible technology which exists, and Option 3 sets 2030 targets based on what will be technically viable in the future. Both two options are preferred by the European Commission but for different timelines.The European Commission has stated both options 3 and 2 are useful to deal with this issue but for different reasons.In the below table, the specific targets for each ingredient by this regulation is stated:

Battery type	Recovery rate by 2025 (Option 2)	Recovery rate by 2030 (Option 3)
Lithium-ion batteries	Co: 90 % Ni : 90 %	Co: 95 % Ni : 95 %

	Li : 35% Cu: 90%	Li : 70% Cu: 95%
Lead-acid batteries	lead: 90%	lead: 95%

1.6. The carbon footprint for industrial and EV batteries

This new Battery regulation (EU) No 2019/1020 together with Annex II set regulations on the carbon footprint of electric vehicle batteries and rechargeable industrial batteries.Option 2 mandates all actors to publish a carbon footprint declaration which should be performed under the "climate change" life cycle impact assessment method recommended in the 2019 Joint Research Center (JRC[2]). The deadline for this option is 1 July 2024. Option 3 is a continuation of option 2 ,which offers that the batteries should be classified according to their carbon footprint by analyzing the distribution of carbon footprint declaration values placed on the EU internal market where category A will belong to the best class with the lowest carbon footprint life cycle impact.This action should take place until 1 January 2026. Continuing on Option 3, the batteries should meet maximum life cycle carbon footprint thresholds by 1 July 2027. These thresholds are identified based on the information collected through the carbon footprint declarations and distribution of carbon footprint performance classes among existing battery models on the market, taking into consideration scientific and technical progress.Options 2 and 3 are both preferred by the European commission only by different deadlines (As of measure 5)

1.7. Performance and durability of rechargeable industrial and EV batteries

durability and batteries expected lifetime

Option 2 for this measure mandates offering information to the customers including the battery type, location of the manufacturer (which enables the traceability of the battery), and a description of the battery. Moreover, this option increases transparency on the durability and availability of performance of the batteries. Therefore, all stakeholders, specifically customers,could have proper access to information and make informed decisions. This option

[2] https://eplca.jrc.ec.europa.eu/permalink/PEF_method.pdf

is in sync with “Empowering Customers “ and “ Extending Producers’ Responsibilities” strategies which were stated in the CEAP.

After applying standards and information gathered by option 2, option 3 will make a long-term contribution. This option introduces minimum performance requirements which result in moving towards more utilized batteries, hence less environmental impact. As of January 2026, rechargeable industrial batteries must fulfill the minimum values set by the European Commission by the delegated act. From the Europena Commission point of view, Option 2 is the preferred option in the short term and Option 3 in the long term.

1.8. Non-Rechargeable portable batteries

As portable batteries are not used in vehicles, this measure is out of the scope of this thesis.

1.9. Recycled content in industrial, EV and automotive batteries

As of 3 previous measures, two different options have been also considered for this measure but with different timeline scopes. The short-term plan is Option 2 which associates with mandating the declaration of the recycled content, and Option 3 as the long-term plan, put mandatory recycled content requirements for lithium, cobalt, nickel, and lead in 2030 and 2035. As a result of these two complementary options, a legal framework will be conducted which later boosts investments in recycling technologies. With the current technologies recycling is more costly in comparison to production from primary raw materials , development of new technologies is essential which is nearly impossible without encouragement caused by the mentioned two options.

1.10. Extended producer responsibility

Extending producer responsibilities is an important part of the CE and has been mentioned in many sections of the CEAP. As a result, It is considered as a measure for this framework as well. This measure will classify Industrial batteries in EPR schemes and apply minor costs which will be mostly covered by the benefits of raising the collection rate of batteries .There has been no more ambitious option suggested by this measure.

1.11. Design requirements for portable batteries

As portable batteries are not used in vehicles, this measure is out of the scope of this thesis.

1.12. Provision of information

This is also about supplying valid information to all economic players within the battery industry in two steps (by applying option 2 and 3 with continuous sequences) as of measure 7. Option 2 for this measure suggests providing information with online and printed labeling which enables delivering tailored information to the customers and end-users of the market and result in promoting more environmentally friendly batteries in the market. Moreover, Option 3 on this measure proposes an electronic exchange system and battery passport based on what has been proposed by Global Batteries Alliance by 1 January 2026. Of course, implementing such a system and battery, passport concept needs administrative costs, but it will pay off in the long term with lower implementation costs and improvements in recycling efficiency and operation. Furthermore, Administrative simplification is another result of an untied electronic exchange system and passport settings for batteries.

1.13. Supply-chain due diligence for raw materials in industrial and EV batteries

In the view of stakeholders, to overcome the social and environmental risks that raw material extraction has such as unfair labor situations and non-environmental friendly operations for extraction (Eynard, Mancini, Eisfeldt, Ciroth, & Pennington, 2018), a mandatory approach is more effective. Option 3 which applies mandatory supply chain due diligence is the preferred choice in comparison to option 2 which considers voluntary participation in the perspective of the European Commission.

These mentioned measures would cover most critical concerns of the battery wastes and apply the minor administrative issues due to the fact that it uses the maximum capacity of digitalisation. They also are consistent with the other EU policies such as the EU's existing environmental and waste legislation and EOL stage of the battery directive which is another value delivered by them. However, other sustainability concerns such as reducing hazardous substances of the batteries has not been covered by these measures. They have been stated in other chapters in this regulation proposal .In the next subsection, requirements which have been proposed for restricting the hazardous substances are provided.

2. Restrictions on hazardous substances

In addition to the restrictions which are already set out in Annex XVII of Regulation (EC), No 1907/2006 of the European Parliament and of the Council, Cadmium, and Mercury are now introduced as hazardous substances which should be excluded from batteries. According to Concerning Batteries and Waste Batteries, Repealing Directive 2006/66/EC and Amending Regulation (EU) No 2019/1020, Batteries used in vehicles to which ELV applies shall not contain more than 0,1% of mercury and 0,01% of cadmium (expressed as mercury and Cadmium metal) by weight in homogeneous material.

At this stage of this report, the proposed regulation of batteries which is based on the CEAP and impact assessment of the current battery directive, Directive 2006/66/EC, and micro plastic initiative also based on the CEAP has been provided.As it can be seen the updates are coming fast and as restricted as possible. ELV is also undergoing an impact assessment and a new proposal which covers heavy duty vehicles is expected in the coming months. Therefore, the direction of this master thesis continued on studying this directive in order to analyze the current situation and come up with potential targets for Volvo Truck in order to face the upcoming legislatives.