D2.1
Intermediate Report Stakeholder Analysis - Roles, Tasks and Responsibilities

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Table of Content

CE-PASS in a Nutshell

CE-PASS is an industrial research project addressing the issue of **sustainability-aware automotive design for the circular economy**, **in the context of highly networked, interoperable ICT systems and platforms**. Austria has a strong industrial base in the automotive sector and this sector is undergoing radical change: firstly, in terms of technology by moving away from the internal combustion engine and its reliance on fossil fuels, to competing powertrain systems such as hydrogen fuel cells and/or battery-based electric drive trains; secondly, corporate due diligence increasingly dictates a view on industrial design that bears long-term sustainability and value retention in mind. At the same time, cloud-enabled, distributed ICT has brought disruptive potential to all sectors, leading to a new wave of automation and digitally driven manufacturing processes.

The project brings together four complementary actors: AVL as one of Austria's foremost automotive design companies; iPoint as a software company with a unique offering of due diligence and compliance-related software tools and with a keen strategic interest in sustainability support for industry; the Institute of Systems Sciences, Innovation and Sustainability Research of University of Graz with its track record in life cycle assessment, circular economy and sustainable supply chain management; and Salzburg Research's "Intelligent Connectivity" group with a track record in digital technologies, having led a highly successful European project NIMBLE (https://www.nimble-project.org/) that developed an open source, B2B supply chain and logistics platform.

CE-PASS Kurzbeschreibung

CE-PASS hat zum Ziel, die Implementierung eines Produktpasses und den damit verbundenen Datenaustausch zu untersuchen und zu bewerten, um die Nachhaltigkeit und Kreislauffähigkeit von Produkten zu verbessern. Das Projekt erforscht Fahrzeug-Design für Nachhaltigkeit und Kreislaufwirtschaft im Kontext von hochgradig vernetzten und interoperierenden IKT Systemen und Plattformen. Das Projekt wird von vier Organisationen getragen, die zueinander hochkomplementär sind: AVL als österreichisches Vorzeigeunternehmen im Automobil-Sektor; i-Point als Software-Firmamdie auf Nachhaltigkeits- und Compliance-Software spezialisiert ist; das Institut für Systemwissenschaften, Innovation und Nachhaltigkeitsforschung der Universität Graz mit seiner Expertise in Lebenszyklus-Analyse, Kreislaufwirtschaft und nachhaltigem Lieferkettenmanagement; und Salzburg Research, die eine Open-Source B2B Lieferketten-Plattform ins Projekt bringt. Wir gehen davon aus, dass in Zukunft ein wachsender Anteil aller wirtschaftlichen Abläufe digital, über Netzwerke passieren wird: Firmeneigene IT-Systeme werden mit digitalen Plattformen interagieren (z.B. in Lieferketten), und es wird Datenflüsse zwischen Firmensystemen und Kontrollsystemen geben, welche Materialflüsse und die Verwendung gefährlicher Stoffe überwachen. Ebenso wird es zum Datentransfer mit öffentlichen Informationssystemen kommen, die z.B. über die Öko-Bilanz von Produkten informieren. Solche vernetzte Systeme müssen vertrauenswürdig und sicher sein und bergen hohe Investitionsrisiken, wenn sie nicht ausreichend interoperabel sind. Aufgabe des Prototyps ist, Fahrzeugentwicklern schon in der Design-Phase Entscheidungshilfen hinsichtlich ökologischer Ziele und Lebenszyklus-Kosten zu geben. Dazu wird ein Software-Prototype als plattform-basiertes Service angeboten, damit die Ingenieure Produktwerterhaltung und Kreislauf-orientierte KPIs optimieren können. Als Anwendungsfälle dienen eine Traktionsbatterie für Elektrofahrzeuge und Komponenten eines Verbrennungsmotors. Ein wesentlicher Aspekt wird die Entwicklung eines digitalen Produkt-Ausweises sein, der Industrie 4.0 Standards mit den Zielen ökologisch nachhaltiger Industrieproduktion kombiniert.

Executive Summary

This document reports on the initial analysis of stakeholders for the CE-PASS project, focussing on the two use cases of the project: the electric vehicle battery (EVB) and turbo chargers for traditional internal combustion engines. The focus is on understanding the role and responsibilities of each value chain actor in order to support the actors' decision -making with regards to circular economy (CE).

The instrument of choice for supporting the emerging CE is the digital product passport (DPP) that is intended to capture all salient information about products and components and that can be used to uniquely identify the products and give access to all information gathered during the product's entire life cycle such as during production, initial use, second use and recycling.

Firstly, the stakeholders for both use cases were identified. For identifying the stakeholders' roles and responsibilities for the EVB use case, the workshop results of Berger et al. (also from University of Graz) were analysed and complemented by findings from literature. In order to get an overview of the roles and responsibilities of the actors along the turbo charger value chain, a focus group workshop was held with several experts from AVL. Their information needs were recorded, analysed and structured.

Overall, the report offers a comparison of the two use cases with respect to their stakeholders and respective roles and tasks. The findings of the report will be used for further identifying the information requirement of each stakeholder which forms the second part of WP 2 of the CE-PASS project. Hence, the intermediate findings presented in this report will be followed up by several other stakeholder analyses at a later stage in the project.

List of abbreviations

BEV	Battery electric vehicle
BoL	Beginning of Life
CE-PASS	Circular Economy Passport
CEAP	Circular Economy Action Plan
DBP	Digital Battery Passport
DPP	Digital Product Passport
EC	European Commission
EU	European Union
EoL	End of Life
GHG	Greenhous gas
ICE	Internal combustion engine
ICEV	Internal combustion engine vehicle
IT	Information Technology
LIB	Lithium-Ion Battery
MoL	Middle of Life
OEM	Orginal Equipment Manufacturer
SCOPIS	Supply Chain-Oriented Process to Identify Stakeholders
SPPI	Sustainable Product Policy Initiative
WP	Work Package
WSC	Workshop Combustion Engine
WSEVB1	Workshop Electric Vehicle Battery No. 1
WSEVB2	Workshop Electric Vehicle Battery No. 2
WSEVB3	Workshop Electric Vehicle Battery No. 3

1 Introduction

1.1 Problem Definition

Over the past decades, the automotive sector has been undergoing a radical change. As it is one of the major contributors of greenhouse gas (GHG) emissions (Agarwal, 2017, pp. 1-3; Klæboe et al., 2014, p. II), it has been facing increasing pressure from both policy makers and the general public to introduce more sustainable solutions (Hirz & Brunner, 2015, p. 1). For this reason, electric and hybrid propulsion systems have been widely considered a convenient alternative to the conventional internal combustion engines (ICE) (Almarew & Brissaud, 2020, pp. 2f.; Ellingsen et al., 2013, p. 113; Hawkins et al., 2012, pp. 53f.; Stampatori et al., 2020, p. 1). They decrease the reliance on fossil fuels as well as, in the case of a renewable electricity supply, significantly reducing emissions during the vehicle's use phases. As a consequence, the electric vehicle (EV) industry shows a current and expected future growth, entailing an immense transformation of the transport and energy system as well as raw material management (Buruzs & Toma, 2017, p. 578; Schulz et al., 2020, p. 182; Stampatori et al., 2020, p. 10).

Accordingly, the demand for electric vehicle batteries (EVB), widely considered as the most critical component of EVs, also grows rapidly (World Economic Forum, 2019, p. 11). However, the production and disposal of EVBs is heavily criticized for its environmental burden (Ellingsen et. al., 2013, p. 113; Hawkins et al., 2013, pp. 56f.; Hirz & Brunner, 2015, p. 2; Stampatori et al., 2020, p. 1; World Economic Forum, 2019, p. 19). Despite the fact that, in the case of a green power supply, EVs' use phase is generally characterized by lower emissions compared to internal combustion engine vehicles (ICEV), their production phase creates higher environmental burdens, e.g., larger global warming potential, higher particular matter formation and eco-toxicity, than the production of ICEVs. This significantly increases the environmental footprint of e-mobility (Bauer et al., 2015, p. 874; Hawkins et al., 2017, pp. 56f.). Also, the EVB's end of life (EoL) phase bears significant challenges (Stampatori et al., 2020, p. 1). Inter alia, the scarcity of systematic and updated information regarding battery assembly, collection, remanufacturing and state of health is hindering an accurate EoL treatment (Ahmadi et al., 2017, p. 11). It thus becomes evident that a close consideration and targeted effort towards a circular design of EVBs as well as a multilateral information exchange becomes crucial. All in all, even though e-mobility is considered a 'green' alternative to ICEVs, it still faces huge, yet unresolved challenges with regards to resource and waste management. In addition to environmental targets, it is furthermore required that EVBs meet safety, integrity, performance and functionality-related requirements (Kiemel et al., 2020, p. 41; World Economic Forum, 2019, pp. 19ff.).

For fostering a circular economy and thus ensuring optimal management and re-use of substances, materials and products, the generation and collection of trustworthy and relevant data is of utmost importance (Heinrich & Lang, 2019, p. 57; Lemos, 2020, p. 8). This information is required to be accessible to all actors involved in the respective supply chain so that they can include circularity considerations into their decision-making. Heinrich and Lang pointed out that "the availability of material data is the core aspect in a functioning circular economy" (2020, p. 57). Here, digitalization represents an essential enabler for accomplishing the transition towards a more CE as increased data gathering and improved connectivity through digitalization allows for information to be shared and managed across the boundaries of companies or countries (European Commission, 2020; Hedberg & Šipka, 2020, pp. 7, 24). Several EU-wide initiatives - such as the European Green Deal, the Circular Economy Action Plan (CEAP) and the Sustainable Product Policy Initiative - refer to the notion of a so-called digital product passport (DPP) as an enabler for information provision and distribution (EC, 2019, 2020; EEB, 2020, pp. 5, 8). Each DPP comprises a unique product identifier and considerable amounts of data collected by various actors along the respective product's value chain (Lemos, 2020, p. 8). The DPP may comprise static data about the product – such as its origin, material composition, dismantling and repair options and EoL handling - as well as dynamic data about the product's individual life (EC, 2019; Lemos, 2020, p. 8). The latter relates to the provision of data on products and their circularity and sustainability performance (EEB, 2020, p. 14).

The Circular Economy Action Plan states that "sustainable batteries and vehicles underpin the mobility of the future" (EC, 2020) and explicitly voices that battery value chains should be designed in a sustainable and circular manner. The CE-PASS project aims at developing a concept and prototype for a DPP for an EVB that fosters its circularity and sustainability dimensions. The corresponding work package (WP), WP2 in CE-PASS, deals with the roles and requirements of the respective stakeholders to be further described in the following section.

Overall, it becomes clear that understanding, responding to and supporting existing and future needs of value chain actors with data and information management, e.g., for product design, supply chain management, compliance, risk management and EoL activities, is highly relevant for promoting circular economy and sustainability.

1.2 Goals of CE-PASS

The overall goal of CE-PASS is to conceptualize and build a prototype system of a digital product passport for an electric vehicle battery. This DPP should be designed using Industry 4.0 standards and combining collected product life cycle data with the data on product's circularity-, sustainability- and stakeholder-oriented perspectives. This enables, firstly life cycle analyses and the calculation of environmental impacts of the product and its components. Secondly, it fosters data exchange between the stakeholders involved and provides access to relevant data. Thirdly, the creation of the DPP promotes circular economy and sustainability along EVBs' value chains, also by making relevant data available to EVB designers and hence bringing forward the adoption of sustainable product design practices in the automotive industry.

In order to gain an in-depth understanding of DPPs within the automotive sector, a second use case besides the EVB is examined in CE-PASS: the internal combustion engine. As has been shown in the introduction, there is a pressing need to improve the sustainability and circularity performance of EVBs and to respond to criticism concerning the environmental and social impact of EVBs. Even though there are already some concepts and starting points for a battery passport for EVBs (e.g., Berger et al., 2022), the proper implementation has not yet happened and is still in its infancy. However, the battery value chain is characterized by a significant complexity (Bai et al., 2020, p. 10) which challenges the identification of information requirements and the conceptualization of a DBP. Hence, the comparison with a potential DPP for the internal combustion engine is considered helpful in order to gain insights regarding a hypothetical DPP for the already well-established ICE value chain and transfer those insights to the newer and more complex EVB use cases. Furthermore, general elements of a DPP with regards to propulsion systems as well as individual requirements for the two use cases can be identified. The comparison of the battery use case and the combustion engine use case further serves to identify differences between a DPP for an already well-established propulsion system and a relatively new vehicle propulsion.

CE-PASS comprises seven work packages, ranging from the conceptualization of the DPP towards the technical implementation. Therewith, all project partners involved are responsible for certain WPs, depending on their respective expertise. The researchers of the University of Graz are assigned to WP 2 and WP 3, dealing with the analysis of the value chain actors and their specific data requirements. This report focuses on the first part of WP 2, which will be presented below.

1.3 Goals of Task T2.1

This report is part of WP2, "Stakeholder and Use Case Requirements Analysis", and more specifically, on Task 2.1 "Stakeholder Analysis". The overall goal of WP2 is to identify and analyze the stakeholders involved in the use cases' value chains in order to identify their requirements for CE solutions. The overall goal of this first part of WP 2 is to determine and map all value chain actors of the use cases and to specify their specific roles, tasks and responsibilities. This will present both use cases and their related value chain actors separately and, in the end, provide a synthesis of both use cases.

2 Use Case 1: The Traction Battery

2.1 Overview

Lithium-ion batteries (in short Li-ion batteries or LIB) are the most commonly used electricity storage system for EVs. Despite the fact that Li-ion batteries are also used for further purposes, e.g., for portable electronics, electric passenger vehicles account for the major share (60%)of global battery demand (Stampatori et al., 2020, p. 1; WEF, 2019, p. 11). As the CE-PASS project focuses on the EVB use case, only EVBs and no batteries for other purposes are regarded within this report. The following section provides an insight into the methods used. Afterwards, an overview of the value chain actors will be presented, followed by a more detailed description of each of the actors.

2.2 Methods

An in-depth stakeholder analysis of the EVB value chain has already been conducted by Berger et al. (2021). For this, Berger et al. (2021) identified all EVB value chain actors and their data requirements by applying the method called supply-chain-oriented process to identify stakeholders (SCOPIS). In order to establish maximum comparability, the same method was also applied for identifying the value chain actors for the ICE use case, which will be further explained in section 3.2.1. The comprehensive analysis of the EVB use case, conducted by Berger et al. (2021), is a basis for the research endeavor in CE-PASS. In addition, Berger et al.'s stakeholder map was used in order to get a well-grounded overview of the involved EVB value chain actors (see Section 2.3.1).

In order to identify the roles, tasks and responsibilities of the stakeholders, the method was applied in a twofold way. Firstly, Berger et al.'s pre-work was used as their stakeholder workshop were screened for information regarding the tasks and responsibilities of EVB stakeholders while screening transcripts of the workshops that they conducted with EVB stakeholders. This in-depth analysis served to identify the actors' roles, tasks and responsibilities. Secondly, as the analysis of the transcripts didn't lead to a sufficiently full picture, it The SCOPIS method was complemented by an extensive literature review, which included recent publications about EVBs and their value chains were considered. They were found by searching for papers that deal with at least one of the stakeholders who was included in Berger et al.'s stakeholder map. The results are shown in Section 2.3.2 will therefore comprise the results of both the analysis of Berger et al.'s transcripts as well as the findings from the literature.

2.3 Results

2.3.1 Overview of Stakeholders Involved

Overall, the EVB value chain can be divided into four stages. The Beginning of Life (BoL) stage is the initial phase of the battery's life cycle, and it includes all steps from the battery design until the final car assembly. The subsequent stage is the Middle of Life (MoL), comprising the use phase of the product, which also includes its inspection and maintenance. After the MoL stage, the battery reaches its End of Life (EoL) and is either used for another purpose, coming to the Battery Second Use (B2U) stage, or it is recycled. In the case of a circular economy, there would be a closed loop between the EoL and the BoL stage as all parts are being recycled and used again. The four stages, their sub-phases as well as the respective actors are presented below. Figure 1 provides a full overview of the actors and their interconnectedness.

Beginning of Life:

- Early design
    - Battery designer/ engineer
    - Vehicle designer/ engineer
- Battery production
    - Supplier of raw materials
    - Supplier of processed materials
    - Supplier of active materials
    - Manufacturer of cell components
    - Manufacturer of battery cells
    - Manufacturer of battery module
    - Manufacturer of battery packs
    - OEM

Middle of Life:

- OEM
- (Contract) dealer for EVs
- User of EV
- Workshop/ maintenance facility

Battery Second Use:

- Repurposing company
- B2U application

End of Life:

- Waste battery collector
- Recycler

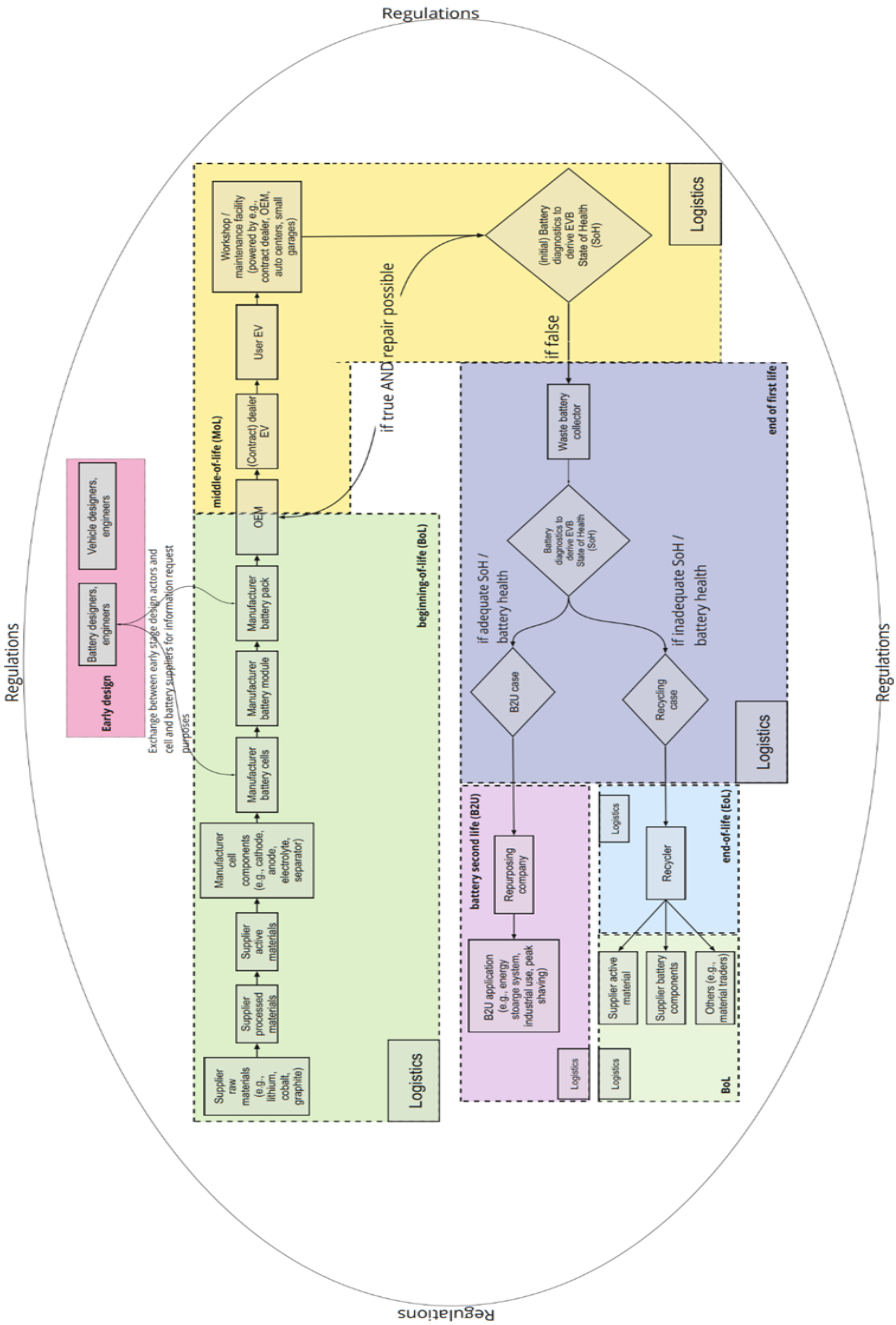

Figure 1: Value chain diagram of an electric vehicle battery (Berger et al., 2022, Appendix A)

2.3.2 Roles, Tasks and Responsibilities of the Stakeholders Involved

Following the overview of the stakeholders involved in the EVB value chain, this section provides a deeper insight into their roles, tasks and responsibilities. In order to simplify, the actors in the manufacturing stage of the EVB are summarized as (raw) materials extractors/ producers and battery (components) manufacturers. Also, the vehicle designers/ engineers are not considered in detail as they only play an indirect role in the creation of an EVB. Both the results of the literature as well as of the analysis of Berger et al.'s workshops (marked as WSEVB1 & WSEVB2) are presented.

Battery designer/engineer:

The major task of these stakeholders is to design and engineer the traction battery. Participants of Berger et al.'s workshops especially stressed the role of designers regarding design for sustainability and design for circularity, as well as the corresponding design for disassembly (WSEVB1). Further, participants emphasized the need for detailed information from stages later in the life cycle, to be included at the beginning of life/ early design phase (WSEVB2).

(Raw) material extractor/producer:

The first and preparatory step during the production phase of an EVB is about raw material extraction. This includes tasks like mining, grinding, and treating raw materials so that they can be further processed and serve for the actual EVB production (Stampatori et al., 2020). Li-ion batteries consist of multiple raw materials, mainly of lithium, cobalt, nickel and graphite. Lithium is extracted from minerals from seawater, brines, ores, and clays, mostly located in Argentina, Chile, Bolivia and China. Also, cobalt occurs in mineral form, for example, in carrollite ($CuCo_2S_4$), a sulfide of copper. The main task of this actor is the extraction of the required raw materials from minerals and its processing and refinement.

participants of the workshops stressed the task of suppliers of materials and components to share information regarding the included substances with OEMs to facilitate and enable compliance (WSEVB1). Also, the general task of delivering fundamental substance level information to value chain partners was mentioned by workshop participants (WSEVB2).

Battery (components) manufacturer:

This role includes multiple actors. First, the cell component manufacturer, as well as the cell manufacturer, are responsible for producing adequate battery cells. During cell manufacturing, their task is, inter alia, to avoid cell overheating through excessive currents. Also, they need to find a compromise between ensuring the highest possible energy density and the maximum safety of the battery cells. With regards to safety, it has to be pointed out that a high number of battery cells is then connected in parallel and in series. Hence, battery manufacturers have to make sure that the cells are produced in a way that they resist potential car crashes, vibrations or varying temperature ranges. (Stampatori et al., 2020)

Whether battery cell manufacturing and battery pack manufacturing are conducted by the same actor or by multiple actors varies between organizations and countries. For example, OEMs in China and Japan are usually in control of both cell and battery pack manufacturing. In contrast, OEMs from Europe often solely control battery pack design and assembly while they import battery cells from elsewhere. In conclusion, the typical tasks of this actor depend on the respective area of responsibility and control. (Stampatori et al., 2020)

Overall, Bai et al. (2020) argue that it is the battery cell and pack manufacturers' responsibility to consider the standardization of cells and battery packs. This would serve to simplify and automate disassembly processes later on in the life cycle of the battery.

Concerning this actor, participants of workshops again voiced the task of these actors to provide the OEM with information regarding their components as early as possible, ideally already in the design phase of the battery, which is usually designed at the OEM as well as compliance reasons (WSEVB1, WSEVB3).

OEM:

In relation to the varying areas of responsibility of the previous actors, also the tasks of an OEM highly depend on their sphere of influence. While Berger et al. (2022) pointed out that an OEM is in charge of manufacturing and assembling the final EVB, Rafele et al. (2020) argued that OEMs usually purchase batteries from outside suppliers. In any case, the OEM requires detailed product-related information regarding the respective EVB in order to adequately handle the battery and proceed with the vehicle assembly. It is the OEM's role to produce the finished vehicle and ensure its high performance and quality. Also, the OEM is responsible for setting the respective warranties (Ellingsen et al., 2013). With regards to supporting a circular economy, the OEM may deal with the assessment of the battery's life cycle impacts which needs to be based on inventory data (Berger et al., 2022). Through that, the OEM's role may be to contribute to decreasing the negative social and environmental impacts along the battery's life cycle as well as to promote the EVB's performance regarding sustainability and circularity. Bai et al. (2020) further mentioned that it would also be advisable that car manufacturers be given the task of recycling their own batteries as the OEMs themselves know best what materials their batteries consist of. Furthermore, some OEMs are also adopting the task of assessing their EVBs' potential second-life options for example, by designing them to be used for stationary applications e.g., for household PV storage (Gohla-Neudecker et al., 2015).

All in all, the OEM's tasks and responsibilities include a wide range of activities, ranging from producing the final batteries through assembling the vehicle and assessing its impact to distributing the car and potentially also recycling its parts.

(Contract) dealer for EVs:

This actor's tasks were not explicitly mentioned either in the workshops or in the literature. It can therefore be assumed that this player is negligible and that the tasks are similar to those of the OEM and workshops as there might be an overlap of actors here.

User of EV:

With respect to the user, it can be argued that the actor's main role is the ownership of an electric vehicle. Hence, the user can be considered to be predominantly an EV user while thereby implicitly being an EVB user. The EV user usually chooses to purchase an EV that most optimally matches his/her driving requirements (Berger et al., 2022). Hence, the user may be interested in general vehicle-related information as well as additional specific information on the EVB, such as its origin, materials, and state of health. Besides the pure use of the vehicle, the user's task is to maintain the car by bringing it to a workshop or maintenance facility. Furthermore, the user is responsible for getting rid of the end-of-life vehicle (ELV) (Nakajima & Vanderburg, 2005). They could either resell the vehicle or take it to a certified collection point for ELVs, such as a car workshop, an OEM or a recycler.

Regarding a future digital product passport, workshop participants also stressed the users' role regarding the provision on battery use data (e.g., charging frequency) (WSEVB2).

Workshop/ maintenance facility:

The main role of an automobile workshop in respect to EVB handling is carrying out the repair, maintenance and refurbishment of the vehicle, and respectively, the EVB (Berger et al., 2022). The goal of this repair or remanufacturing process is to make the battery fit for extending its use for the same application (Wrålsen, 2021). Stampatori et al. (2020) pointed out that the purpose of remanufacturing emerges from the fact that the performance of some, but not all battery cells and parts, may degrade over time. The remanufacturing and refurbishment of the battery hence serves to make all battery cells and components ready for further use. Foster et al. (2014) put it into the following words "Remanufacturing has to do with replacing cells within a battery that can no longer hold sufficient charge to meet the standards for use in a vehicle." They argue that the task of the workshop is thus to disassemble the battery, remove deficient cells and replace them with functioning cells, and finally reassemble the battery. Besides their active role within the repair, remanufacturing and refurbishment process, the workshop may provide support if the first use of an EVB has come to an end (Berger et al., 2022). Concerning the EVB, this stakeholder is responsible to maintain the EVB's health status and related decision situations. In addition, this stakeholder is also seen in the role of a provider of information regarding the service of the battery and critical incidents of the battery (WSEVB2).

Waste battery collector:

As has been mentioned above, the ELV is brought to a collecting facility by the EV user. This could either be an automobile workshop, a car manufacturer, or a recycler. Depending on the sphere of influence and responsibility of those actors, it may be that they carry out waste battery collection themselves or deliver the batteries to a separate collection point. The task of the waste battery collector is hence to collect and sort the batteries and decide on whether they should be recycled or used for another purpose. (Nakajima & Vanderburg, 2005)

Workshop participants also mentioned that waste battery collectors could be the actors who carry out the battery diagnostics for assessing the state of battery health (WSEVB2).

Repurposing company (B2U):

This actor is responsible for enabling a second life for an EVB, after its first life has come to an end (Berger et al., 2022). Stampatori et al. (2020) argued that the idea of repurposing an end-of-life EVB is based on the fact that if an EVB's performance is lower than 80%, it is not considered to be suitable for EV applications any more. Nevertheless, it may be beneficial to use the battery for another applications, such as for large or small stationary storage applications. For example, battery packs can be repurposed to become a part of a smart grid by being used as energy storage systems (ESS) (Ahmadi et al., 2015).

Hence, the activity of this actor is based on a feasibility assessment of the battery with regard to remanufacturing, recycling, and repurposing (Foster et al., 2014). Thus, the main role of this actor is to identify a suitable application for the second use of the battery and to support the repurposing process. preparation for the application of choice. The related tasks contain the following (Ahmadi et al., 2015; Foster et al., 2014): 1) sorting the end-of-life batteries, 2) assessing and selecting the batteries for a suitable second-use application, 3) disassembling the packs into modules and dismantling batteries into cells, 4) testing the cells, 5) reassembling the cells into a new configuration while installing new battery modules, packs and electronics, 6) developing the control system for the new application and activating the battery for its new application. Regarding this complex process, Foster et al. (2014) made it clear that each battery case may be related to an individually designed configuration process. This relates to the uniqueness of each repurposing process, which calls for a specifically adapted design and repurposing process.

Overall, B2U extends the battery's total life cycle by delaying the definite end-of-life stage. The role of the repurposing company is hence substantial for enhancing sustainable resource management and circular economy (Reinhardt et al., 2019).

Battery second life application:

As has been explained above, the EVB could be used for another application, such as energy storage systems, after it has terminated its first use. The actor who uses the end-of-first-life battery can be summarized with the term battery second life application. The actor gets the battery from the repurposing company and then uses the re-configurated battery ~~in its new configuration~~. Workshop participants recognized these actors as providers of information for BoL stakeholders, contributing to recyclability and gaining more knowledge about battery cell quality (WSEVB2).

Recycler:

As each battery and its containing cells are at some point in time unable to be used for any application and hence enter their definite end of life (Foster et al., 2014). In order to regain material for new battery production, EoL batteries can be recycled (Bai et al., 2020). One of the central tasks of a recycler is to identify adequate recycling possibilities for the respective batteries (Berger et al., 2022). Thus, this actor disassembles the battery and its cells into their components (Foster et al., 2014). The recycler must then efficiently sort components of different chemistries in order to simplify the separation processes. Afterwards, the recycler's task is to decide how to properly handle each component while keeping the process efficiency. Therefore, the battery recycler assesses the battery and its components in a detailed manner, considering all materials as well as the chemical composition (Berger et al., 2022).

Workshops participants also emphasized that recyclers could also deliver information about the recyclability of batteries to the battery producers (WSEVB2).

3 Use Case 2: The Combustion Engine

3.1 Overview

The second use case within the CE-PASS project besides the traction battery is the combustion engine, or more specifically, the turbocharger of a combustion engine. Whereas the stakeholder map itself was drawn for the entire combustion engine, it was considered to be useful for the focus group workshops that were held for this use case, to focus on a certain component of the ICE. This allowed for being able to dive more into detail and get more concrete results within the workshops. A team of AVL experts decided during a focus group workshop, which aimed at the validation of the stakeholder map, to focus on the turbocharger as part of the combustion engine. This decision was made because for this part of the combustion engine there already exists the use case of refurbishing used turbochargers and this process could possibly be further facilitated with the help of a DPP. A turbocharger increases the performance of an internal combustion engine by converting the thermal energy from exhausted gas into mechanical energy, which is then used to drive the compressor, that increases the air pressure before the air enters the engine and thereby increases the air mass flow, which enters into the cylinders (Chen et al., 2022). The following section provides an insight into the methods used for the combustion engine use cas, as well as the value chain actors and their roles.

3.2 Methods

For identifying the stakeholders of the combustion engine value chain and their corresponding roles, tasks and responsibilities, different methods were used as described in the rest of this section.

3.2.1 SCOPIS Method

For the identification of relevant stakeholders, the supply chain-oriented process to identify stakeholders (SCOPIS), developed by Fritz et al (2018), was used. This process consists of multiple steps, as illustrated in Figure 2.

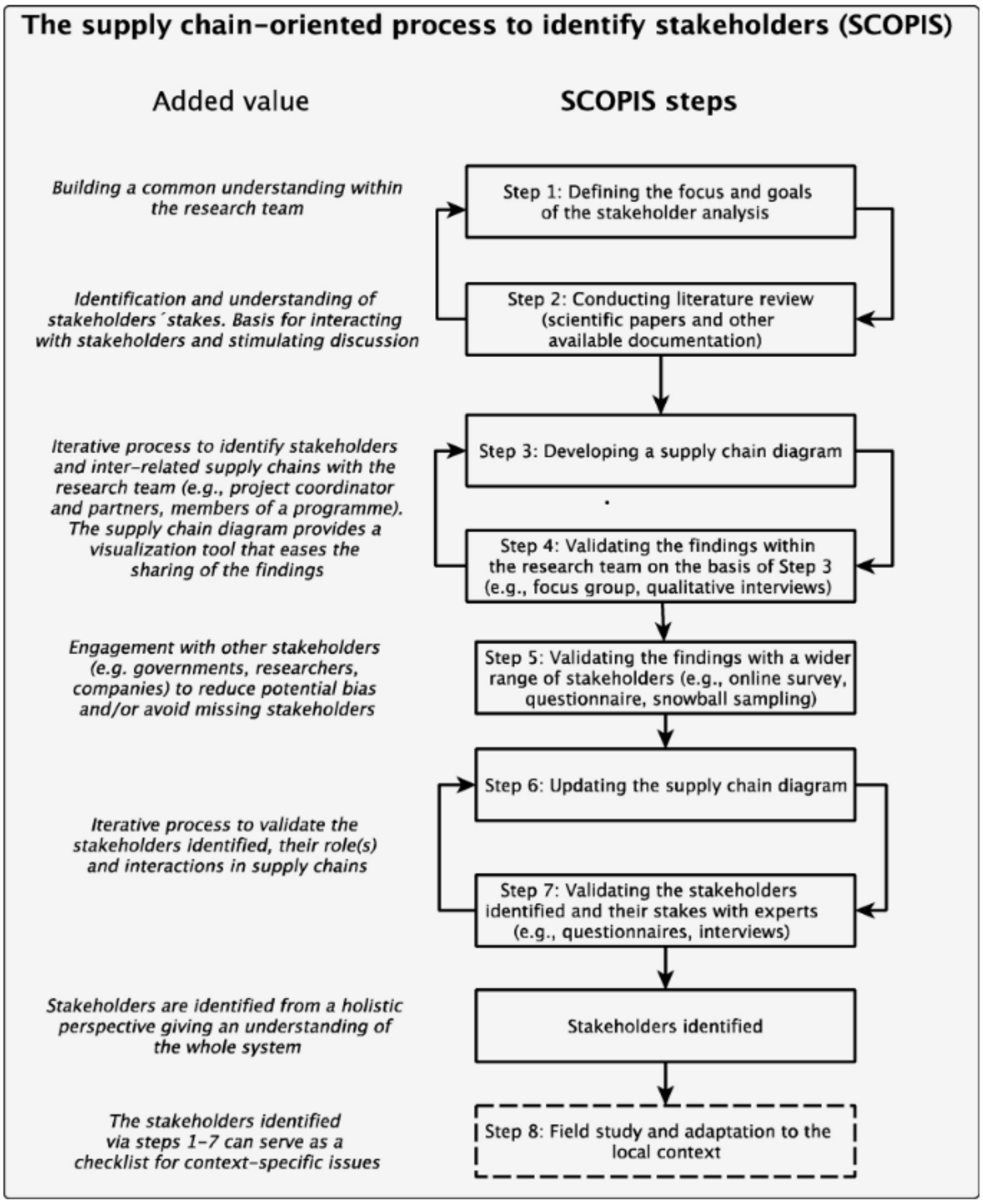

Figure 2: Overview of the SCOPIS method (Fritz et al., 2018, p. 67)

Following, the previously generic steps are described according to the application of the method to the combustion engine use case.

Step 1: Define focus & goals

The overall goal of this step is to inform about the value chain of the combustion engine and the stakeholders. It enables the research team to decide which specific part of the combustion engine should be used as an exemplary part to build a DPP. The different stakeholders identified in this process should then help in the process of requirements gathering.

Step 2: Literature Review

The literature review was carried out in a couple of steps, as described below.

1. Definition of a first set of keywords:

Firstly, the keywords used for identifying relevant literature were determined by the research team. Below, an overview of the keywords is given:

Overview:

- “combustion engine“ AND “supply chain“
- “combustion engine“ AND “value chain“
- “combustion engine“ AND “stakeholder“
- “gasoline engine“ AND “supply chain“
- “gasoline engine“ AND “value chain“
- “gasoline engine“ AND “stakeholder“
- “gas engine“ AND “supply chain“
- “gas engine“ AND “value chain“
- “gas engine“ AND “stakeholder“
- “combustion engine“ AND “end of life“
- “combustion engine“ AND “life cycle assessment“
- “combustion engine“ AND “LCA“

2. Get a full set of related papers

After the determination of the key words, they were used to carry out a search, using the scientific search engines SCOPUS and Web of Science. This process resulted in the identification of 1104 potential papers. After the removal of the duplicates, 610 papers remained in the set for the literature review.

3. Title and Abstract Screening

The titles and abstracts were screened by the research team. Firstly, the selection criteria for the inclusion of papers were determined. Papers that were only related to supply chain management or battery electric vehicles were excluded, given that they will not provide insights regarding the research aim in this use case. After that, firstly, the research team, consisting out of two members, independently screened the titles of papers and then discussed the decision regarding the exclusion of papers collectively. After the final decisions regarding the exclusion of papers, the research team agreed to continue the process with 187 papers. Of these 187 papers, the abstracts were screened regarding suitability to contribute to the identification of the most relevant stakeholders. Again, firstly the abstracts were screened by both members of the research team independently and then the decisions of the individual members were discussed and further elaborated. After the final decision, 104 papers remained. After the abstract screening, the papers were further analyzed in detail. During this process, 21 papers had to be excluded as the research team didn't get access to the full text of the papers. Again, the research team analyzed the remaining papers independently and decided together, after discussing potentially irrelevant papers, to keep 59 papers in the literature sample for an in-depth analysis. The overall process of the literature review as illustrated in Figure 3 below.

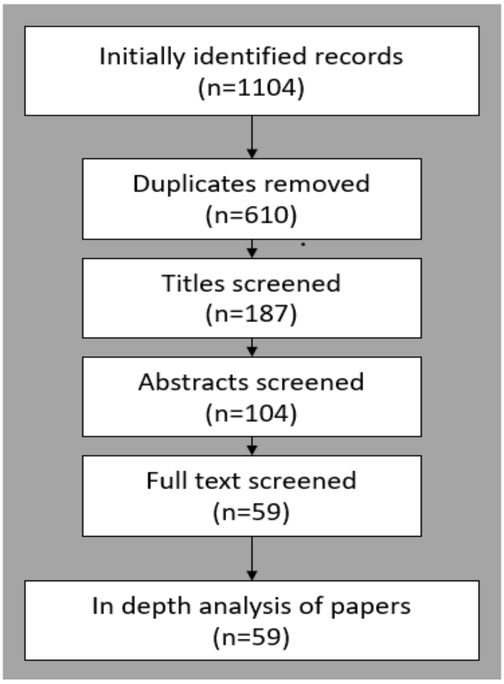

Figure 3: Overview of the literature review

Step 3: Development of a supply chain diagram

The selected papers were ~~then~~ analyzed using the software package MaxQDA, which facilitates the analysis of text documents by enabling the coding of specific text passages. During the analysis, different stakeholders were identified in the different life cycle phases, BoL, MoL and EoL, and the result of the analysis was a first draft of a stakeholder map of potentially involved stakeholders. The design of the stakeholder map was carried out using Miro, the online visual collaborative whiteboarding platform (https://miro.com/index/).

Step 4: Internal Validation with the research team

The first draft of the stakeholder map was internally discussed and adapted. The internal validation was carried out by a subgroup of the overall institute research team including experts in the field of digital battery passports, sustainability assessment and heavy-duty powertrain life cycle assessment.

Step 5 and 6: Update the stakeholder map and external validation

After the internal validation, the stakeholder map was updated and validated with external experts from the industry partner AVL, during the workshop with AVL's experts in the field of combustion engine. The contributions of these experts were implemented and further it was also decided to focus on the component "turbocharger" within the combustion engine for the further identification of the requirements for a digital product passport.

3.2.2 Focus Group Workshop

In order to identify the information requirements of stakeholders along the ICE supply chain, the use of a focus group workshop was considered very beneficial. Group interviews or so-called focus groups may be used to incentivize interaction between the interview partners. In this case, the focus group was organized as a workshop with the aim of identifying different information requirements which should be included in a digital product passport as well as discussing the roles, tasks, and responsibilities of the previously identified stakeholders. The stakeholder map was also again validated by seven experts in a specific task within the overall workshop. The focus group workshop took place online, and the collaboration tool MIRO was used for working on the different tasks. The workshop was recorded, transcribed, and analyzed content-wise by using the software package MAxQDA.

3.3 Results

3.3.1 Overview of Stakeholders Involved

The SCOPIS process led to the identification of the following stakeholders involved in the combustion engine supply chain.

Beginning of Life:

- Raw material extraction
  - Iron ore supplier
  - Bauxit supplier
  - Oil supplier
- Material Processing and Production
  - Iron/Steel producer
  - Aluminum producer
  - Polymer producer
- Parts Producer
- Component Production
  - Component producer
  - Accredited producer replacement parts
  - Non accredit producer replacement parts
- Engine Assembly
  - OEM
  - Engine assembler

Middle of Life:

- Distribution
  - OEM
  - Distributor

- Official Maintenance
    - Official repair shop
    - Official spare parts dealer
- Unofficial Maintenance
    - Unofficial repair shop
    - Unofficial spare parts dealer
- Use of Vehicle
    - Initial user
    - Reuser for the same purpose
    - Reuser for another purpose
- Inspection Authorities

End of Life:

- Dismantler
- Shredding facility
- Recycling facility
- Waste management institutions

The different stakeholder and their corresponding interconnections are shown in Figure 4 below.

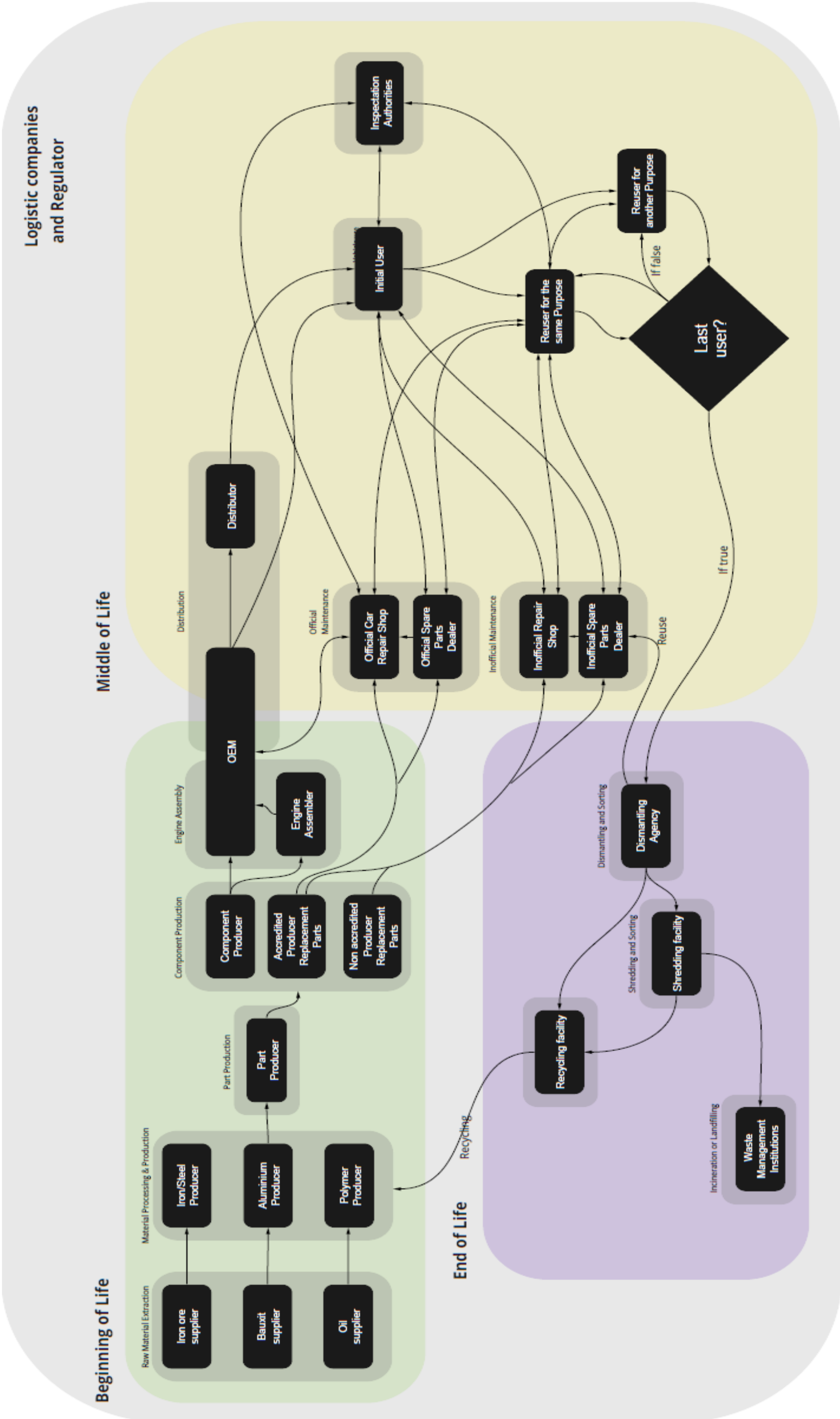

Figure 4: Value chain diagram of an internal combustion engine

3.3.2 Roles, Tasks and Responsibilities of the Stakeholders

In this section, the roles, tasks and responsibilities of the different actors, are described. For the sake of simplicity, some categories of actors are presented using higher level categories. For instance, iron ore supplier, bauxite supplier and oil supplier are summarized into raw material extractors.

Raw material extractor:

The raw material extractors are extractors of iron ore, bauxite and raw oil extractors. Raw material extractors are responsible for the extraction of the resources out of the reservoirs and provide the base for the production of materials, which are then used to produce the combustion engine and, respectively, the turbocharger. They are the first actors in the production phase of the life cycle and are responsible for the origin of the primary raw material. This is also supported by literature sources in which it is stated as well that this actor's main role is to extract the required raw materials (e.g., Simons & Azimow, 2021).

Material producer:

The next category of stakeholders is the material producers, who create the materials to produce the combustion engine and the turbocharger. The iron and steel producers are responsible for the creation of the corresponding materials, while the aluminum producer creates aluminum out of bauxite and the polymer producer creates polymer out of oil. The material producers are responsible for the fulfillment of the purity requirements of the created materials.

Part producer:

This actor creates parts which are necessary for the turbocharger, out of the materials supplied by the materials producer. Based on the design and drawing information provided by the component producer, the different parts of the turbocharger are manufactured. The parts producer is responsible for ensuring that the material requirements of the parts are fulfilled.

Component producer:

The component producer manufactures the turbocharger out of the parts which are supplied by the parts producer. The component producer manufactures the turbocharger according to the design requirements of the OEM or, respectively, of the engine assembler. Further, the component producer is responsible for the compliance with the quality requirements of the turbocharger.

Engine Assembler/ OEM:

The engine assembler or OEM integrates the turbocharger into the combustion engine. Therefore, the engine assembler or OEM is responsible for the correct incorporation of the turbocharger. The end-of-line testing is also carried out by the engine assembler/ OEM, thus being responsible for the flawless working of the turbocharger. Further, the OEM can refurbish used or not flawlessly working turbochargers and resell them to maintenance and repair shops. Finally, the OEM also has the task of refurbishing of turbochargers, testing and guaranteeing the quality of the refurbished turbochargers.

Distributor:

Following the integration of the turbocharger, the whole car including the turbocharger is sold by the distributor. The distributor is responsible for the fulfillment of the customer demands, also with regard to the turbocharger.

Initial user:

The initial user buys the car from the distributor. Usually, there is no specific interest of the initial user regarding the turbocharger itself, and the main role of this actor is to use the car as a whole. The responsibility of the initial user is to carry out the mandatory service and maintenance requirements regarding the turbocharger and to seek a repair shop when the warning lights indicate a problem with the combustion engine. These maintenance requirements are determined by the OEM and the specific instructions are included into the maintenance directive.

Official and unofficial repair shop:

The official as well as the unofficial repair shops carry out the maintenance and repair tasks associated with the turbocharger. They exchange and repair the different parts of the turbocharger in the case of maintenance or damage. The official repair shop has only access to the original spare parts, while the unofficial repair shop can also use replica spare parts.

Official and unofficial spare parts dealer:

The official and unofficial spare parts dealers supply the parts, which are required for the repair shops to carry out the required maintenance and repair tasks. The responsibility of the spare parts dealers is to provide the repair shops with the suitable and demanded spare parts. The official spare parts dealer has access to the parts provided directly by the OEM only, while the unofficial spare parts dealer can also sell replica parts.

Inspection authorities:

Inspection authorities are responsible for the technical inspection of the overall car and for the turbocharger. They are responsible for declaring that the car is in adequate working condition.

Reuser for the same purpose:

This actor includes the buyer of a used car and the buyer of a used turbocharger. This actor's tasks and responsibilities are identical to those of the initial user. Only the regular maintenance and irregular repair activities must be initiated by the user for the same purpose.

Reuser for a different purpose:

In this case, the turbocharger is used in a different way as intended by the OEM. A turbocharger can, for instance, be used to increase the performance of a given combustion engine such as through tuning.

Dismantler:

The dismantler disassembles the end-of-life vehicle into its parts and components. This process also includes the separation of the turbocharger from the overall combustion engine and the dismantling of the turbocharger itself. The responsibility of the dismantler is to disaggregate the turbocharger to a level which makes it possible for the shredding company to separate the material for recycling.

Shredder:

After the dismantler has disaggregated the vehicle and the turbocharger, the components that are not qualified to be reused or refurbed, are reduced to small pieces by the shredder. The shredder is responsible for sorting and separating the resulting small pieces.

Recycler:

The recycler delivers the pieces which qualify for recycling. The recycler, which produces the secondary raw material, is responsible for clarifying how much of the recycled material can be mixed to the primary material in order to get the same quality requirements. Further, the recycler is responsible for the purity requirements of the secondary raw material. The recycler also delivers the secondary raw materials to the material producers, which then either deliver it directly to the parts producer or use it in the creation of new materials, which are then delivered to the parts producer.

Waste management institution:

The final stage in the value chain is represented by the waste management institution. The task of the waste management institution is to dispose of the material, which was not eligible for recycling. An example here would be the thermal utilization of the remaining waste of the turbocharger.

4 Conclusions and Outlook

The report shows the intermediate results of the stakeholder identification process. The relevant stakeholders along both value chains were identified and their corresponding tasks, roles and responsibilities were presented. For the identification of stakeholders, the methods were slightly different, given that for the traction battery use case already detailed information and material was available within the research group whereas the research regarding the combustion engine had to start from scratch. Despite the slightly different approach, the results were processed and presented in a way which makes the use cases comparable. The main differences and similarities between the stakeholders are shown in Table 1 below.

Table 1: Comparison of EVB and ICE use case

Life cycle phase	Difference and similarities between EVB and ICE
Beginning of life	The overall phases of the production process of the turbo charger and the traction battery can be considered similar: Extraction of raw materials, production of the components of the battery and the turbo charger and assembly of the components to finally create the battery and the turbocharger. The main differences in the BoL phase are the materials, which are used to produce components (e.g., production of battery cell vs. production of turbine housing) and the different ways of manufacturing the different parts and components.
Middle of life	Also in the MoL phase, the overall stakeholders and roles are similar. The battery as well as the turbocharger are part of a vehicle, which is sold by a distributor to a user, and workshops/maintenance facilities provide repair and maintenance services. The differences are again to be found in the details on how the different tasks are carried out. For instance, the repair process of a turbocharger differs strongly from the repair process of an electric vehicle battery. The role of the user is in both cases similar, namely the use of the car, in which the battery or turbocharger are located and the execution of regular maintenance as well as repair activities of this car. One difference in this phase is, that the turbocharger can also be used for different purposes, namely tuning of ICE, while this possibility of use does not exist for the battery.

End of life	In this life cycle phase strong differences arise. At the end of the use phase of a turbo charger there are two different possibilities: the turbocharger is used as spare part for another ICE or recycled, where then the materials are usually shredded and the different metals are recovered. In the case of the battery, it is assessed if the battery is appropriate for a second life application or not. In the case of the battery being appropriate for a second life, it is usually used in a different application than before and in the case of recycling the materials, which are used in the battery are recovered as good as possible. Here, a strong difference to the combustion engine can be detected, given that the turbo charger is either used for the same purpose or recycled while the battery is used in another application or recycled.
Battery second life	This life cycle phase is only present in the traction battery use case. The battery is used in a different way than before, for instance as energy storage system instead of in a vehicle.

The identification of the different stakeholders of both value chains will be used for the identification of the corresponding information needs and the definition of requirements for the creation of a DPP prototype. Summarizing, it can be stated, that although there are similarities in the stakeholder roles in both cases, the differences in the details are going to influence the necessary information, which will be included in the DPP. In the beginning of life phase especially the different materials used are important and the more complex production of the battery, which will lead to more necessity of information sharing. In the use phase, the in-use data of car users is important regarding the eligibility of the battery for a second life application, while there is no need for in use data for the turbo charger. The end-of-life scenarios for both use cases vary strongly and therefore, especially here the information requirements may as well vary strongly. While in the beginning of life phase information points could be more generic, like for instance “bill of materials” or “assembly and disassembly information” there will be a need for more specific information points in the use phase, especially regarding potentially dynamic user data for the assessment of the second life option, and in the end-of-life phase, where the two use cases vary strongly.

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