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ABSTRACT

The European Union and France consider the transport sector as a priority in terms of sustainable development, with the goal of reducing emissions by 90% by 2050. To achieve this, the electrification of the vehicle fleet is seen as a solution, if electricity production is decarbonized, and end-of-life management of electric vehicles is sustainable. Sales of electric and hybrid cars are growing in Europe thanks to government policies promoting the purchase of these vehicles and consumer demand for perceived sustainability.

The electric and hybrid cars currently entering the vehicle fleet will reach the end of their life, requiring appropriate management of end-of-life vehicle processing facilities. The management of electrified ELVs requires dedicated equipment and adequate training of personnel for the management and disposal of electric batteries. According to the results of a survey conducted among VHU centers, they are preparing for the arrival of these new types of vehicles, but most of them have not yet received any electric or hybrid vehicles. More than half of them sat that they have the necessary information to do so, while nearly half have trained their staff in battery removal. Approximately one-third of the centers plan to train their personnel in the future.

In the short term (by 2025-2030), the volume of electrified ELVs will remain low, allowing the sector to prepare for the future. Due to the slow pace of vehicle turnover, the flow of thermal and electrified ELVs will not be balanced before 2040. By then, the thermal vehicle fleet will be in steep decline and electrified vehicles will be largely in the majority. However, the diversity of electrified powertrain architectures, including those still featuring an Internal Combustion Engine, is another important factor to consider in the preparation and organisation of ELV processing facilities.

The results of the study highlight the economic impacts of car electrification on the ELV sector. Due to increasing interest in the circular economy, the sale of used parts is on the rise, increasing from 357 EUR per ELV in 2021 to 715 EUR per ELV in 2035. In addition, a nascent activity of reselling mobility batteries after refurbishment could reach around 64 M EUR in 2035. Specific material valorisation of parts for electrification will also become significant, estimated at almost 27 M EUR in 2035.

To adapt to the new stages of processing electrified ELVs, ELV processing facilities will need to invest in personnel training and necessary equipment, representing a total investment cost of 20.5 M EUR over the 2022-2040 period. The forthcoming complexity for the sector to seize economic development opportunities during this transition period is also highlighted, due to the necessary developments in the current operation of ELV processing and increasing diversity.

1. Project context and objectives

1.1. Context

ELECTRIFICATION OF LIGHT VEHICLE SALES ACCELERATES UNDER THE IMPACT OF PUBLIC POLICIES

The year 2020 was marked by a tightening of the European CAFE (Corporate Average Fuel Economy) regulations governing CO_2 emissions from new passenger cars, forcing carmakers to keep sales emissions below the threshold of 95 grams of CO_2 per kilometer (NEDC, New European Driving Cycle). The effect of this tougher legislation has been to significantly increase the penetration of electrified vehicles in new car sales, both in France and across Europe. In many cases, this increase has been accompanied by tax incentives at the time of purchase, such as bonus/malus schemes.

The new ambitions of the European Green Deal, confirmed on 14 July 2021, will amplify demands to reduce emissions. The European Commission's latest proposals call for a 55% reduction in CO_2 emissions from new passenger cars by 2030, followed by an end to emissions as of 2035, so that the fleet will be virtually emission-free by 2050.

The electrification of vehicles is seen as an essential way of achieving these objectives. The matter of the energy-mix and the transition from fossil fuels to less carbon-intensive energies is also at stake to enable the transport sector to reduce its greenhouse gas (GHG) emissions by 90% by 2050.

Transport currently accounts for a quarter of the European Union's greenhouse gas emissions[1]. In France, in 2019, transport generated almost a third of the GHG emissions[2]. The breakdown of emissions from the transport sector is as follows[3]:

- 54% from cars;
- 23.4% from heavy goods vehicles and buses;
- 15.8% from commercial vehicles;
- 1% from two-wheelers;
- 5.7% from non-road transport.

The transport sector is a priority for sustainable development policy within the European Union. The Green Deal proposed by the Commission aims to achieve a 90% reduction in emissions from the transport sector by 2050. To achieve this, the Commission has launched its strategy for sustainable and intelligent mobility. The strategy encompasses a number of sustainable mobility actions; in relation to road transport the strategy is to promote the use of zero-emission vehicles, renewable and low-carbon fuels, and related infrastructure. The strategy foresees that:

- by 2030, at least 30 million vehicles will be zero-emission vehicles;
- by 2050, virtually all new cars, vans, buses and heavy goods vehicles will be zero-emission vehicles.

In France, this political will to promote low-emission vehicles has been transposed into regulations. Hence, the law "n° 2021-1104 du 22 août 2021 portant lutte contre le dérèglement

1 European Environment Agency. Link to the website https://www.eea.europa.eu/fr/themes/transport/intro#:~:text=While%20most%20of%20the%20total%20greenhouses%20are%20from%20the%20EU.

2 Commissariat général au développement durable (CGDD). Link: https://www.notre-environnement.gouv.fr/rapport-sur-l-etat-de-l-environnement/themes-ree/defis-environnementaux/changement-climatique/emissions-de-gaz-a-effet-de-serre/article/les-emissions-de-gaz-a-effet-de-serre-du-secteur-des-transports#:~:text=En%202019%2C%20le%20transport%20is,repr%C3%A9sentait%2022%20%25%20of%20total%20national.&text=Champ%20%3A%20FFrance%20m%C3%A9tropolitaine%20and%20Out%2Dmer%20of%20the%20EU.

3 Ministry for Ecological Transition. Link: https://www.statistiques.developpement-durable.gouv.fr/edition-numerique/chiffres-cles-du-climat-2022/11-emissions-de-ges-des-transports

climatique et renforcement de la résilience face à ses effets" stipulates an end to the sale of new passenger cars emitting more than 123 grams of CO_2 per kilometer.

The electrification of the car fleet is seen as a means of achieving "zero emissions". For this to be effective, the decarbonization of electricity production as well as the sustainable management of the production chain and of the end-of-life of electric vehicles are essential.

Although European sales figures are still low, the growth in sales of electric and hybrid vehicles has accelerated due to government support, improvements in the range of these vehicles offered by the automotive industry, and a growing desire on the part of consumers to buy sustainably.

CHANGES IN THE ENGINE MIX OF THE FLEET WILL HAVE CONSEQUENCES FOR THE TREATMENT OF END-OF-LIFE VEHICLES (ELV)

Given the significant technical differences between cars with internal combustion engines (ICE) and those with electric or hybrid engines, the increase in the proportion of the latter in the vehicle fleet will have consequences for the management of ELV. Indeed, even if the number of hybrid or electric ELV entering approved treatment centers remains marginal in France today (around a thousand units in 2019 out of more than a million ELV[4]), professionals in the ELV treatment sector are beginning to take a close look at this issue by setting up internal working groups within their main trade associations (MOBILIANS and FEDEREC).

In view of this change, the ELV processing sector needs to be in a position to anticipate the impact of this major development as far as possible, by having the relevant analytical data at its disposal.

1.2. Objectives

In this context, the aim of this study is to carry out:

- an assessment of the extent to which professionals in the ELV treatment sector are prepared for the switch to electric vehicles;
- an assessment of the expected volume of electric and hybrid ELV in 5, 10, 15 and 20 years;
- an in-depth analysis of the technical, organizational and economic impact of this change on the ELV sector.

[4] According to ADEME - Observatory of the ELV sector.

2. Methodology

2.1. Scope

The ELV scope of this study covers private cars, light commercial vehicles with a gross vehicle weight rating (GVWR) of less than 3.5 tons (vans), mopeds, motorbikes, and motorized quadricycles in France.

2.2. General work plan and resources

This section presents the four phases of the study and the means used to obtain the results presented in sections 3 to 6.

2.2.1. Phase 1 - Analysis of equivalent work carried out in Europe

The electrification of the vehicle fleet and its impact on the ELV processing chain is a topical issue that affects, to a greater or lesser degree, all countries within and outside the European Union.

The aim of this phase is to:

- identify and analyze equivalent impact studies;
- identify the measures taken by industry players to electrify the vehicle fleet.

After conducting initial research at European level, equivalent work in Europe was researched and analyzed in depth for eight countries:

- Germany;
- Belgium;
- Spain;
- Finland;
- Italy;
- Norway;
- The Netherlands;
- Portugal.

The in-depth analysis was based on a literature review and interviews with national representatives of ELV treatment facilities. The representatives contacted are listed in the table below.

Country	Actor contacted
Germany	UBA - Regina KOHLMEYER
Belgium	FEBELAUTO - Catherine LENAERTS
Spain	SIGRAUTO - Manuel KINDELAN
Finland	SUOMEN AUTOKIERRÄTYS - Juha KENRAALI
Italy	CONFEDERAZIONE AUTODEMOLITORI RIUNITI - Alfonso GIFUNI
Norway	AUTORETUR - Guro KRISTINE MILLI
Netherlands	ARN - Janet KES
Portugal	VALORCAR - Ricardo FURTADO

Table 1: National representatives of the ELV sector contacted

2.2.2. Phase 2 - Assessment of the level of preparedness of the ELV processing sector in France to cope with the shift in the vehicle fleet towards electric vehicles.

The aim of this phase was to take stock of the situation in terms of the preparedness of the French ELV treatment sector for the electrification of the vehicle fleet.

The following resources were mobilized for this phase:

- 12 interviews with sector representatives (FEDEREC and MOBILIANS) and managers of certain ELV centers;
- a visit to an ELV center to demonstrate battery removal);
- an online survey of all approved ELV centers in France (see questionnaire in the separate appendix to this document).

Phase 2 is therefore structured as follows:

- a section describing the current state of the ELV-e[5] and ELV-h[6] management sector which presents the roles of the players and the flows in the French sector;
- a section on the prerequisites for the treatment of ELV-e and ELV-h;
- a section presenting the results of the national survey of approved ELV centers in France regarding their level of preparedness for the electrification of the vehicle fleet.

2.2.3. Phase 3 - Assessment of the expected volume of electric and hybrid ELV in the next 5, 10, 15 and 20 years

The projections are based on the tool and work conducted by BIPE-BDO with and for the PFA ("Plateforme Filière Automobile & Mobilités") as part of the *World Automotive Powertrain Outlook* WAPO in 2021.

This modelling and forecasting work consists of scenarios for the development of the motorization mix in Europe and the rest of the world, from which the data and results for France are extracted. They are direct references of the PFA and its six main members and global players in the sector—two carmakers (Renault and Stellantis) and four Tier 1 suppliers (Forvia, Michelin, Plastic Omnium, and Valeo)—internally for their 'product' strategy and with the French and European public authorities.

2.2.4. Phase 4 - in-depth analysis of the technical, organizational, and economic consequences of this change for the ELV sector

The aim of phase 4 is to present the technical, organizational, and economic consequences for the ELV sector of changes in the vehicle and ELV fleets over different timeframes.

The aim of the technical section is to characterize electrified vehicles and highlight the differences between them and internal combustion vehicles to better understand the consequences for ELV, particularly in terms of:

[5] ELV-e is the acronym for "100% electric end-of-life vehicles".
[6] ELV-h stands for "hybrid end-of-life vehicles".

- motorization architectures;
- specific and useful parts and components, in particular to serve the vehicle fleet;
- the material composition of vehicles.

The aim of **the organizational section** is to outline the adaptations and new stages required for the treatment of an electrified ELV by ELV centers compared with the treatment of an internal combustion ELV, as well as the training and equipment required to conduct these new steps in the treatment of electrified ELV.

Finally, **the economic section** aims to present the economic consequences on the industry of reprocessing the transformation of ELV, and more specifically:

- the evolution of the economic spin-offs and losses generated for the ELV treatment sector by the electrification of the vehicle fleet, distinguishing between the impacts of the various activities:
  - Second-hand parts dismantled from ELV, mainly for reuse or remanufacturing;
  - Residual parts dismantled from ELV for repurposing or material recovery;
  - Valorization of the remaining parts of the ELV after dismantling.
- the investment required for ELV centers in terms of training and equipment for processing electric and hybrid ELV.

The data used and their respective sources are indicated in the body of the report (see section 6).

3. Phase 1 - Analysis of equivalent work carried out in Europe

The objectives of this chapter are as follows:

- identify and analyze equivalent work in terms of impact;
- identify the measures taken by industry players in response to the electrification of the car fleet.

3.1. Equivalent work in terms of impact

To date, no study of the impact of the electrification of the car fleet on the activity of ELV centers has been identified in the countries studied (Germany, Belgium, Spain, Finland, Italy, Norway, the Netherlands, and Portugal).

3.2. Measures taken by industry players to prepare for the electrification of the car fleet

Discussions with national representatives of the ELV sector have yielded relevant information on the organization and/or processing of electric and hybrid ELV. The list of national representatives contacted is presented in Table 1 in the methodology section.

The table below shows the types of relevant information identified in each country.

	Germany	Belgium	Spain	Finland	Italy	Norway	The Netherlands	Portugal
Training & Raising awareness	No	Yes	Yes	No	Yes	No	Yes	Yes
Reference systems and treatment standards	No	Yes	No	No	No	No	Yes	Yes
Specific ELV centers approval	No	Yes	No	No	No	No	Yes	No

Table 2: Types of relevant information identified in each country

The table below describes the information.

Country	Summary of key information
Germany	No relevant action or specificity has been identified for Germany at the federal level. Note: In terms of ELV management, Germany has a decentralized system where marketers meet their extended producer responsibility (EPR) mainly through individual systems and draw up individual contracts with authorized ELV centers. In this sense, there is no national ELV body. Car manufacturers may be taking steps to address the electrification of the vehicle fleet through their individual ELV management systems, but these steps have not been identified.
Belgium	FEBELAUTO[7] has defined battery management standards for electric and hybrid vehicles in collaboration with the sector and has summarized the conditions required for the treatment of these vehicles by ELV centers. The standards drawn up by FEBELAUTO cover both intact batteries at the end of their life and damaged batteries. FEBELAUTO has created a separate approval for ELV centers managing electric and/or hybrid ELV: "approved ELV PLUS center". The standards that PLUS approved centers must meet are available in the link below: https://www.febelauto.be/public/FEBELAUTO-NORM-English-Version-revised-april-20.pdf These PLUS-approved ELV centers have trained their staff to dismantle batteries from electric and hybrid vehicles and have adapted facilities to make the job easier as well as secure storage areas. PLUS approved centers ensure that the battery modules, the battery itself, and the original vehicle can be traced. This traceability makes it possible to know which car the battery came from and, if the battery is dismantled, to know from which battery the modules that were separated belonged to.
Spain	Since 2021, SIGRAUTO[8] has been providing ELV centers with safety information (posters, videos, etc.) and training on the removal of intact batteries based on information available in the IDIS database.[9] The Royal Decree 265/2021 of April 4th, 2021 makes it compulsory for ELV center employees to obtain a training certificate before they can process ELV-e and ELV-h. To this end, SIGRAUTO has developed specific training in the treatment of ELV-e and ELV-h. Upon completion of this training, operators receive an official certificate recognized by the public authorities. SIGRAUTO also provides financial assistance to ELV centers wishing to take the training and receive the certificate. The qualifications required to obtain the certificate are set out in Annex VI of the Royal Decree 265/2021[10].

[7] FEBELAUTO is the Belgian organization for the management of end-of-life vehicles and industrial batteries (Independent Collective System).
[8] SIGRAUTO is the Spanish association for the environmental treatment of end-of-life vehicles.
[9] Link to the IDIS website: https://www.idis2.com/
[10] Link: https://www.boe.es/buscar/doc.php?id=BOE-A-2021-5868

Country	Summary of key information
Finland	Discussions are underway between the players in the ELV treatment sector to prepare for the electrification of the vehicle fleet, but no relevant action or specificity has been identified for Finland.
Italy	In 2022, the Italian association of vehicle dismantlers (Confederazione Autodemolitori Riuniti), in collaboration with the University of Rome, planned two days of awareness-raising/information sessions on ELV-e and ELV-h management. A guide for vehicle dismantlers was to be drawn up following the conference.
Norway	The Norwegian public authorities have established regulations for the treatment of ELV-e and ELV-h, particularly regarding the management of electric mobility batteries: • Regulation on safety when working on and operating electrical installations[11] , which lays down safety measures and working methods; • Regulation respecting the transport of dangerous goods by land which, among other things, establishes safety measures for the transport of batteries[12].
Netherlands	ARN[13] has developed three initiatives to prepare ELV-e and ELV-h treatment centers: • Training based on a standard for handling high-voltage equipment[14]. A first version of the training material was produced in 2015 and a second, more comprehensive version in 2019. This training was offered to a maximum of one person per affiliated ELV center. • A standard for the treatment of ELV-e and ELV-h that all ARN-affiliated ELV centers must comply with to be able to manage these types of ELV. This standard came into force on September 1st, 2022. ARN will organize audits to check that its centers comply with the standard.[15] • A starter box containing the tools and personal protective equipment needed to treat ELV-e and ELV-h. The starter box is sold at a discount if the ELV center follows the second version of the training course[16]. In addition, ARN has developed a predictive model to estimate the quantities of batteries that will be on the market in the future and therefore the quantities of batteries that their centers will need to process. ARN has reviewed the differences in terms of spare parts between thermal and electric vehicles (based on the International Dismantling Information System, IDIS database). According to this review, apart from the battery, there are few differences between the two types of vehicles.

[11] Link: https://lovdata.no/dokument/SF/forskrift/2006-04-28-458
[12] Link: https://lovdata.no/dokument/SF/forskrift/2009-04-01-384?q=forskrift%20om%20farlig%20gods
[13] Eco-organization for end-of-life vehicles and heavy electric mobility batteries in the Netherlands.
[14] Link: https://www.nen.nl/elektrotechniek/werkvoorschriften/e-voertuigen
[15] Link: https://www.kzd.info/
[16] Link: https://www.linkedin.com/feed/update/urn:li:activity:6913127031010435072/

Country	Summary of key information
Portugal	For the past three years, VALORCAR[17] has been offering ELV centers training courses in the handling of electric and hybrid vehicles. The training covers the safety measures and equipment needed to manage these vehicles and their batteries. VALORCAR provides information on the dismantling of electric batteries. VALORCAR has published two guides: one on the dismantling of ELV, including a section on ELV-e and ELV-h[18], and another on taking charge of electric/hybrid vehicle batteries[19].

Table 3: Summary of key information by country

[17] Collective system (different from an EO in the sense that Valorcar is independent) for the ELV sector in Portugal for the ELV sector in Portugal.
[18] Link: https://www.valorcar.pt/images/uploads/library/valorcar_GuiaDesmantelamentoVFV2019_v8_1581950091.pdf
[19] Link: https://www.valorcar.pt/images/uploads/library/guia-GestaoRBA2019_valorcar_final__1580742609.pdf

4. Phase 2 - Assessment of the level of preparedness of the ELV processing sector in France to cope with the shift in the vehicle fleet towards electric vehicles

The objectives of this chapter are as follows:

- Take stock of the ELV-e and ELV-h management sector in France;
- Establish the prerequisites for the treatment of ELV-e and ELV-h;
- Assess the state of readiness of ELV centers regarding the electrification of the vehicle fleet in France.

The sub-sections below correspond to the results associated with the objectives of the chapter.

Note: according to discussions with ELV centers, electric and hybrid mopeds, motorbikes, and quadricycles have begun to be processed by specialist centers. The survey of approved ELV centers revealed that some centers have already received this type of vehicle. However, this remains marginal and these vehicles are therefore not dealt with specifically in the following sections.

4.1. Overview of the ELV-e and ELV-h management sector

The ELV management sector is facing the early stages of the transition from thermal cars to 100% electric or hybrid cars.

On the regulatory front, reforms are accompanying this transition. European and French regulations on the management of ELV and batteries are changing rapidly:

- A new European regulation on batteries and battery waste is expected;
- A revision of Directive 2000/53/EC of September 18th, 2000 on ELV is in progress;
- An implementing decree published at the beginning of December 2022 stipulates the obligation to set up an eco-organization or approved individual systems for the ELV sector[20] .

It is therefore important to point out that this section presents the current state of the industry and not its future situation.

In France, ELV destined for destruction (whether internal combustion, 100% electric, or hybrid) must be processed by ELV centers. However, there are several possible routes before vehicles are considered to be end-of-life and therefore destined for destruction, depending on the condition of the vehicles and the choices made by those involved (notably owners and dealers). The main options for ELV-e and ELV-h are as follows:

- vehicles that owners want to part with when they buy a new vehicle (1:1 trade-in);
- broken-down vehicles;
- vehicles involved in accidents;
- vehicles whose owners wish to dispose of to obtain a certificate of destruction;
- vehicles from impound yards;
- ELV without batteries brought in by authorized repairers or dealers once the battery has been removed.

The figure below illustrates the scenarios presented above (green boxes). It also shows the players (blue boxes) and the different flows (arrows of distinct colors depending on the flow: see legend). The sub-sections that follow detail the roles and interactions between these players. However, the analysis focuses on the role of ELV centers.

[20] Decree no. 2022-1495 of 24 November 2022 on the management of end-of-life vehicles and the extended producers responsibility of passenger cars, light vans, two- or three-wheeled motor vehicles, and motor quadricycles.

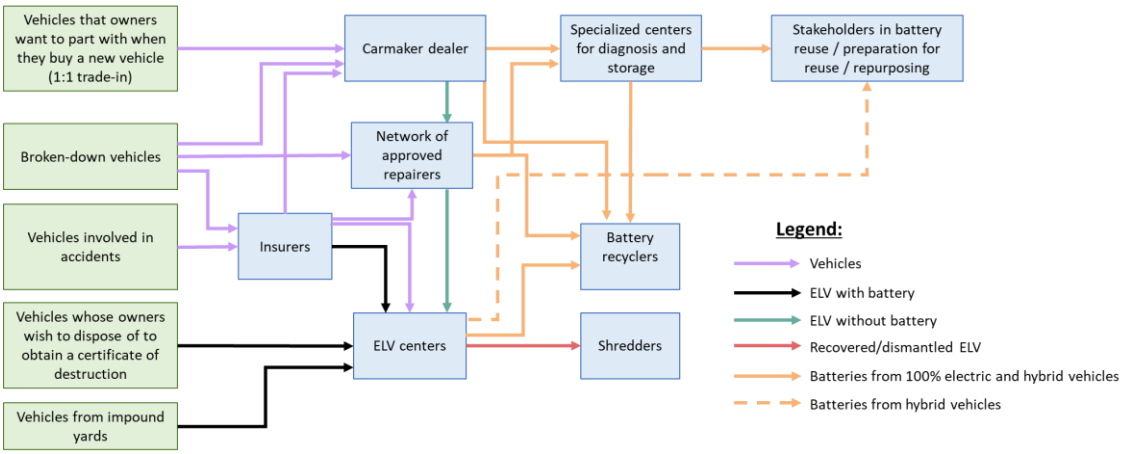


Figure 1: Current management system for electric and hybrid ELV in France

4.1.1. Network of approved repairers and dealers

Electric and hybrid vehicles are sent to the manufacturer's approved repair networks or to dealerships in the following situations (see Figure 1):

- vehicles that owners want to part with when they buy a new vehicle (1:1 trade-in);
- broken-down vehicles (depending on the case, through the insurance company);
- vehicles involved in accidents (generally through the insurance company).

Once the 100% electric or hybrid vehicle has been taken to a repairer or dealer, an initial diagnosis is made to determine the problem with the vehicle and/or the state of the battery. This professional will then either repair the vehicle and/or its battery in situ or send it to a specialist center (if the issue is too complex). At this center, an in-depth analysis is conducted. Following the analysis, several options are possible depending on the seriousness of the situation: the battery is repaired by changing the faulty modules (which are sent for recycling) and the vehicle is put back on the road or the vehicle is sent to the end of its life (ELV for destruction) and the vehicle's battery is removed beforehand by the center.

Vehicle manufacturers provide repairers and dealers with the information and tools they need to conduct this initial diagnosis. Communication and knowledge sharing (often confidential) between the manufacturer and the repairer/dealer regarding battery diagnosis and management are made possible by the approval and contractual arrangements between these players. It should be noted, however, that some manufacturers find it difficult to assess the state of health (SoH) of the batteries in their own vehicles; this reflects the difficulty that all the players in the industry have in acquiring this diagnostic capability.

Once the battery is removed from the vehicle, the battery and the vehicle follow two different routes:

- ELV-e and ELV-h without batteries are transported to ELV centers in the same way as combustion engine ELV[21];
- There are two options for batteries that have been removed, depending on the results of the initial diagnosis:
  - sent to a specialist diagnostic and storage center if there is any chance that the battery is still in good condition;
  - send directly to recycling if not.

[21] It should be noted that this practice raises questions with regard to ELV regulations, since ELV centers only take back vehicles free of charge when they are complete.

4.1.2. ELV centers

4.1.2.1. Collection and transport

Electric and hybrid vehicles are directed to ELV centers in the following situations (see Figure 1):

- vehicles involved in accidents deemed technically or economically irreparable[22];
- vehicles whose owners wish to dispose of them to obtain a certificate of destruction;
- vehicles from impound yards;
- ELV without batteries brought in by authorized repairers or dealers once the battery has been removed.

At present, few end-of-life electric or hybrid vehicles (and therefore batteries) are collected and processed by ELV centers. In 2020, around 1,000 ELV-e and ELV-h were received by some 290 ELV centers, according to the centers' annual declarations to ADEME via SYDEREP, which represents 17% of ELV centers. Only 20 ELV centers received more than 10 ELV-e and ELV-h in 2020. Some ELV centers are authorized by manufacturers, which implies a formal agreement to share information and procedures for the treatment of ELV-e, ELV-h and their batteries.[23]

Figure 2 shows the evolution from 2017 to 2020 of the amount of ELV-e and ELV-h received by ELV centers.

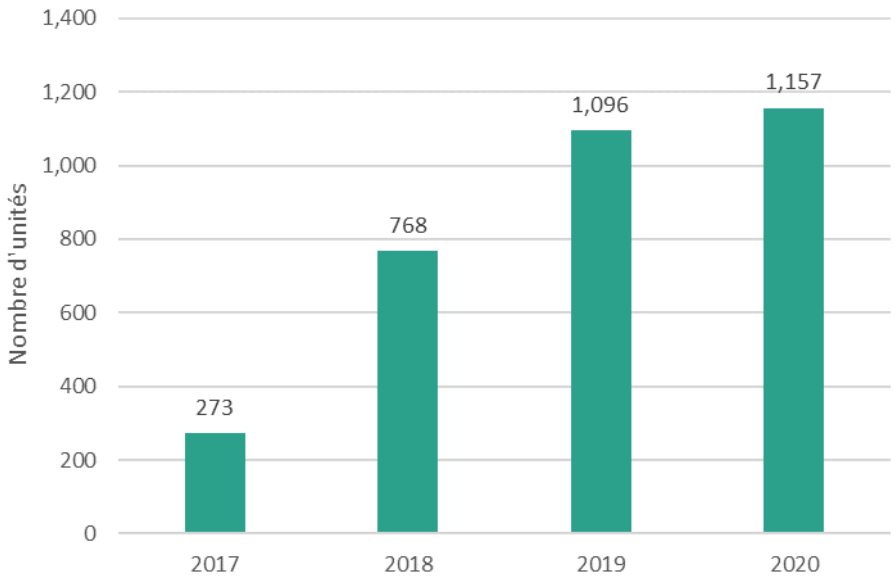


Figure 2: historical trend between 2017 and 2020 of ELV-e and ELV-h received by ELV centers

The electric or hybrid vehicles arriving at ELV centers today are:

[22] Some vehicles held by insurers (vehicles declared to be economically irreparable) can be sent to ELV centers, which then decide whether to convert them into ELVs (for destruction) or to sell them to car professionals for repair. Only vehicles that have been declared technically irreparable by an expert are in fact ELVs and must be destroyed.

[23] For more information on the figures for ELV treatment, including ELV-e and ELV-h, please consult the annual reports published by ADEME on the ELV treatment sector. Link: https://librairie.ademe.fr/

- in most cases, vehicles which have been involved in an accident and are technically irreparable or for which the cost of repair exceeds the residual value of the vehicle ("written-off" cars);
- and as a minority, vehicles at the end of their life, vehicles with low residual economic value that the owner wishes to dispose of.

Most of the end-of-life hybrid vehicles arriving at ELV centers are the first electric 'Priuses' marketed in 2005-2006.

End-of-life electric vehicles represent an even more marginal flow, as they are still new and have not yet reached the end of their useful life. Those that have reached the end of their life are mainly the 'Zoé' (marketed in 2012/2013).

When ELV-e and ELV-h are transported with their batteries (a situation that occurs mainly when the vehicles can no longer be driven due to an accident or breakdown), the battery should in theory be disconnected before the ELV-e and ELV-h are transported, either by the breakdown mechanic or by the transporter from the receiving ELV center, so as to cut off any electrical current between the battery and the rest of the vehicle. This should be done to reduce the risk of fire and electrocution. In practice, however, this is generally not the case. In fact, the disconnection systems, which vary greatly in shape from one vehicle model to another, are not always accessible (either because of their original construction or because they were deformed/blocked in the event of an accident). In addition, some disconnection systems involve the destruction of the dedicated part.

4.1.2.2. Treatment and storage at ELV centers

Notes:

1. The treatment of ELV-e and ELV-h by ELV centers is a recent and marginal activity. The number of ELV-e and ELV-h received in 2020 was around 1,000. The practices described below correspond to the current practices identified in the ELV centers interviewed. ELV-e and ELV-h treatment practices are governed by ELV regulations. However, these regulations do not include any specific provisions for ELV-e and ELV-h and their batteries; to date, there are no specific regulations in this area.
2. Almost all ELV centers do not have the capability to diagnose the state of the battery.
3. Some ELV centers receive ELV without batteries, in which case the treatment of these ELV-e or ELV-h is identical to that for thermal ELV.

4.1.2.2.1. Pre-sorting between ELV at risk or in good condition

The first operation conducted when electric or hybrid vehicles are received at the center is a sorting into two categories:

- vehicles that have been involved in an accident and could be at risk of catching fire (high-risk vehicles), and which must therefore be put on hold pending a technical assessment by the manufacturer or the expert appointed by the insurer;
- vehicles in good condition or damaged but not at risk.

This initial sorting is based on in-house expertise. In the most advanced ELV centers, the person in charge of this sorting has a checklist that enables them to determine whether the vehicle is at risk or not.

Some of the electric or hybrid vehicles received by ELV centers will not be depolluted and dismantled; this is particularly the case for certain vehicles deemed economically unrepairable (written-off) by the insurer's technical appraisal and which are sold directly as is to professional repairers (garages in France or abroad, for example) so they can be reconditioned. In this

situation, the vehicle's repairs must be approved by a qualified "damaged vehicle" (DV) surveyor[24] so that the vehicle's driving bans can be lifted[25] .

4.1.2.2.2. Battery power cut

For vehicles arriving at the ELV center in good condition or after an accident that poses no risk, the first operation prior to storage consists of disconnecting the electrical system linking the battery to the rest of the car (if this has not already been done during transport). This is done to prevent the risk of fire or electrocution.

The cut-off system varies according to the vehicle; it may be a circuit breaker, a switch or a cable that must be cut permanently (destructive cut).

Vehicles that have been involved in an accident and could be at risk of catching fire cannot be cut. For these vehicles, the ELV centers must wait for the technical expertise commissioned by the insurer or manufacturer. Generally speaking, the configuration of certain accidents may make this operation impossible. In these cases, other means must be used. External technical expertise (manufacturers, technical experts) may be required if the ELV center has not developed this expertise in-house or acquired it through the transfer of knowledge from a third party.

4.1.2.2.3. Storing the ELV before removing the battery

ELV-e or ELV-h that are deemed to be at risk and have not been electrically disconnected are ideally stored in a dedicated area with special safety measures (sufficient physical separation between vehicles, fireproof tarpaulins on each vehicle, signage indicating risks and instructions); these safety measures may vary between centers.

In practice, however, the vast majority of ELV centers do not yet have such an area; what is done in most cases is to place at-risk vehicles in the same area as other ELV, but at a safe distance, which varies depending on the center (from one to around five meters).

ELV-e or ELV-h that are in good condition or that have been involved in an accident but are not at risk are stored with the thermal ELV. The most advanced centers mark electric or hybrid vehicles with stickers to distinguish them easily from thermal vehicles.

4.1.2.2.4. Reading the manufacturer's manual

Before starting physical operations on the vehicle, the operators read the vehicle manual supplied by the manufacturer with the aim of considering the specific technical instructions for each vehicle. However, this manual only deals with cases where the vehicle and its battery are intact.

The International Dismantling Information System (IDIS)[26] is a database of procedures for dismantling ELV, including ELV-e, ELV-h and their batteries. ELV centers can also consult this database for information on dismantling procedures.

4.1.2.2.5. Checking the electrical battery cut-off system

First, the operators will check that the battery has been disconnected. If this has not already been done, the system is switched off.

4.1.2.2.6. Removing the battery

LOCATION

[24] An expert will only follow up if the vehicle is covered by the DV (Damaged Vehicle) procedure.
[25] See articles R. 327-1 to R. 327-3 of the Highway Code. Link to the website: https://www.legifrance.gouv.fr/codes/section_lc/LEGITEXT000006074228/LEGISCTA000006159618/#LEGISCTA000020517916
[26] Link: https://www.idis2.com/

In practice, ELV centers do not yet have a dedicated area for battery removal, which is conducted in areas that are also used for processing thermal ELV. Ideally, battery removal should take place in a dedicated area, marked off with signage (such as warning tape).

STAFF QUALIFICATIONS AND EQUIPMENT

The personnel conducting the battery removal operation must at *least* have received electrical clearance training (usually B2XL). When the vehicle is at risk (for example, when it is impossible to remove the service plug), the accreditation TST ("Travail Sous Tension") is essential. They must wear dedicated personal protective equipment (PPE) for tasks with live equipment (insulated gloves, helmet with protective face shield) and must use dedicated tools (insulated screwdrivers, etc.).

STEPS

There are several scenarios for this operation, depending on the condition of the vehicle or the location of the battery in the car (outside or inside the bodywork, at the rear or in the middle of the vehicle, etc.).

Note: the battery in 100% electric vehicles is usually located on the outside under the floor of the vehicle, but in hybrid vehicles the battery can be found in a number of places, including:

- on the outside under the floor;
- inside the bodywork, either at the rear or in the middle (see Figure 6).

The different scenarios are described below.

- For ELV-e in good condition and ELV-h in good condition with their batteries outside under the floor: the batteries are removed by following the eight steps below. A single, trained person can conduct the work, and it generally takes between 30 and 60 minutes.

  1. The ELV is first raised using a bridge that hooks onto the vehicle's support points (a two-post bridge, for example) and gives access from below to the vehicle's entire floor (see figure below).



Figure 3: Vehicle raised by a two-column bridge (source: Oreilo)

  2. Depending on the vehicle model and the battery temperature control system, certain components may need to be removed, such as the battery temperature control fluid and overlapping parts that prevent access to the battery.
  3. Once access to the battery is possible, the cable linking the battery to the rest of the vehicle is disconnected.
  4. The electrical state of the battery is checked using a no-voltage tester to ensure that the battery is disconnected.

5. A lifting table (see Figure 4) is positioned under the elevated vehicle in order to place the battery on it once it has been removed from the ELV. The lifting table consists of:
    i. a wooden pallet which is the section of the lifting table that will be in contact with the battery and which isolates the battery from the metal parts;
    ii. a metal interface between the wooden pallet and the table mechanism to provide more support surface if required, given that the size of the batteries can vary;
    iii. the lifting table mechanism.

    The lift table is raised to the point where the wooden pallet is in contact with the battery.



Figure 4: Lift table (source: Re-source by INDRA)

6. The battery is then detached from the body and placed on the lifting table. It is then lowered back down to ground level.
7. The battery connection points are then covered with adhesive tape to protect them from water ingress.
8. Finally, the battery is transported using a forklift truck and stored in a dedicated container (see section 4.1.2.2.7).

- <u>For ELV-h in good condition with the battery inside the bodywork (in the middle or at the rear)</u>: The battery is generally accessible through the vehicle's doors, so removing it does not require a bridge that hooks onto the vehicle's support points (a two-post bridge, for example). The procedure is the same as in stages 2 to 4 above. The battery is then removed with the help of a forklift truck and a dedicated handling kit (see Figure 5 below). The battery connection points are then covered (as in step 7 above) and the battery is stored in a dedicated container (as in step 8 above).

  Note: ELV-h have increasingly large batteries that extend under the floor. In the future, this scenario may no longer be necessary, as the removal of these batteries

will require a bridge that hooks onto the vehicle's support points (a two-post bridge, for example).



Figure 5: Forklift truck and handling kit

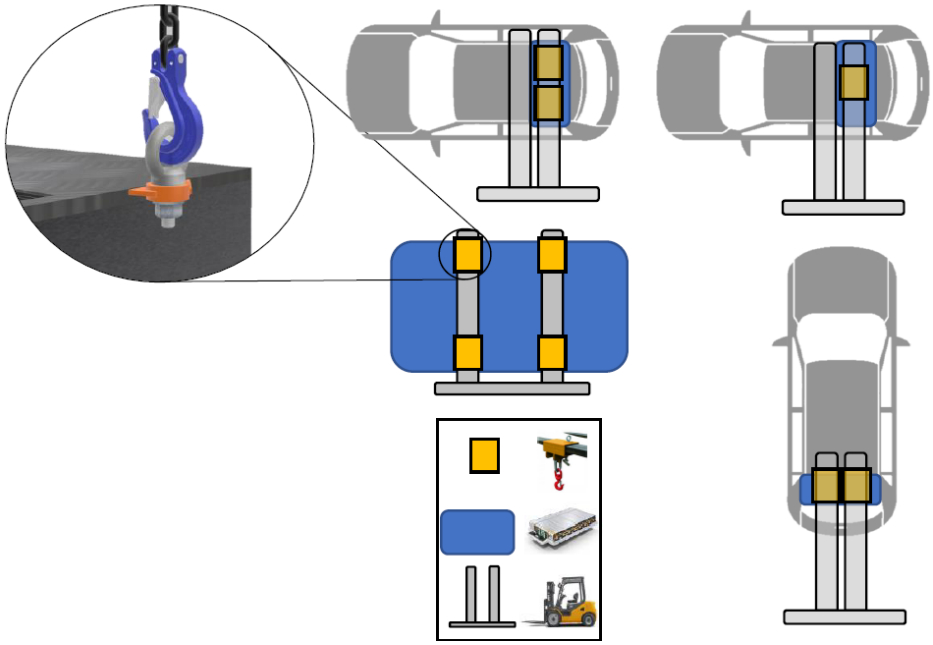


Figure 6: Different battery location options for hybrid vehicles and handling kit diagram
Legend - Yellow square: handling hook; blue rectangle: battery; grey bars: forklift truck

- For ELV-e and ELV-h that were damaged in an accident: there is no standard procedure for removing the battery. The method of removal will be defined on a case-by-case basis, depending on the type of damage to the vehicle.
  Note: As part of its R&D approach, INDRA is preparing guidelines for the treatment of vehicles involved in accidents, depending on the vehicle model and the type of accident. INDRA has also created a network of Electric Vehicle Expert Centers (EVECs) to which it has licensed its expertise. These EVECs will be able to manage all vehicles at risk.

4.1.2.2.7. Storage of the removed battery

The battery will be stored until it is sent for recycling, reuse, or repurposing (see glossary). The ability to find outlets for batteries varies from one ELV center to another.

Regarding individual storage containers, batteries are stored in dedicated containers depending on the condition of the battery:

- P901 containers (batteries in good condition);
- P908 (damaged batteries for which the risk is managed);
- P911 (damaged batteries for which the risk is not managed).

In terms of storage facilities, some ELV centers store batteries in a closed, well-ventilated room, while others store them outside, out of the rain. The batteries, or the containers containing them, are often placed on a concrete slab with a fluid retention system.

Some more advanced centers (capable of diagnosing the SoH of the battery: see next section) use special storage conditions.

Ideally, batteries intended for reuse or repurposing should be stored in a dedicated building and regularly charged and discharged to maintain their condition.

4.1.2.2.8. Battery status diagnostics

To be able to direct the batteries towards channels other than recycling, the ELV center must be able to conduct a diagnosis of the condition of the battery fitted to the vehicle, which should determine:

- the battery's SoH, measured by the ratio between the battery's maximum charge and its rated capacity;
- the level of danger posed by the battery, particularly for ELV deemed to be at risk.

The battery's SoH is an assessment of its energy storage capacity and reflects its residual economic value. The SoH will determine the recovery outlet (reuse, repurposing or recycling). This diagnosis is made by accessing the battery management system (BMS). There is no single method for determining SoH; each manufacturer may propose a method specific to the make/model.

In practice, almost no ELV centers currently have a tool for diagnosing the SoH of the battery.

4.1.2.3. Transport and treatment after disassembly and battery removal

4.1.2.3.1. ELV-e and ELV-h

Once the batteries have been removed, the ELV-e or ELV-h will follow the same circuit as thermal ELV:

- depollution (used oils, cooling fluids, brake fluids, etc.);
- dismantling of certain mandatory parts (e.g., tires) or valuable parts that will be resold on the second-hand market (e.g. rims, bumpers).

The depolluted and dismantled ELV-e and ELV-h are then sent to a shredder to separate and recover the metals and sometimes the other non-metallic materials. Depending on the center, the depolluted and dismantled ELV may be compacted before being sent to the shredder.

4.1.2.3.2. Batteries

Note: Today, electric vehicle batteries generally reach the end of their life for use in vehicles when their capacity is less than 80% and they can no longer meet the initial requirements for electric vehicles (e.g., limits the car's range).

Unlike batteries used in consumer electronics (e.g., laptops and mobile phones), the batteries used in electric cars can still retain 70-80% of their initial capacity. These batteries can no longer meet the initial requirements for use in electric vehicles, but they could provide sufficient capacity for less demanding applications such as stationary energy storage, or for mobility applications that do not require an elevated level of autonomy.

Electric or hybrid vehicle batteries can be:

- either reused or repurposed;
- or recycled to obtain secondary raw materials.

Today, most batteries are sent to specialist recyclers. This is because most of them come from vehicles that have been involved in accidents and are therefore not reusable. There are outlets for reuse, repurposing, or recycling, but these are currently marginal, particularly given the small volumes of batteries collected. In France, there are two main players active in the recycling of electric and hybrid vehicle batteries: SNAM and EURO DIEUZE INDUSTRIE (Sarpi by Veolia). Battery recycling operations are described in the appendices (see Appendix B).

Recyclers organize the transport of electric vehicle batteries between the ELV center and their recycling facilities. They sign B-to-B contracts with car manufacturers for the transport and processing of the batteries from the electric vehicles they put on the market. The transport is often subcontracted to the recyclers and is conducted by semi-trailers, generally with a capacity of 40 tons.

The transport of lithium-ion electric mobility batteries (most batteries used in electric and hybrid vehicles) is subject to ADR regulations under code 3480. As of today, in France, these batteries are not classified as hazardous waste[27]; this is not the case in all EU countries. In Spain, the Netherlands, and certain German Länder, used lithium-ion batteries are considered to be hazardous waste.

Batteries must be transported in specific containers depending on their condition:

- P901 (batteries in good condition). These containers can be made of wood or plastic to ensure watertightness in the event of impact.
- P908 (damaged batteries).
- P911 (high-risk defective batteries). These containers are equipped with a fire extinguishing system, such as a degassing valve or carbon dioxide snow.

These containers are also used for intermediate storage at ELV centers.

4.2. Requirements for ELV-e and ELV-h- treatment

The following sections describe the various prerequisites for the treatment of ELV-e and ELV-h.

It should be noted that the elements presented in these sections correspond to the best practices identified during discussions with ELV center representatives and do not derive from any official standard or regulation. To date, there are no standards or regulations in this area in France.

4.2.1. Equipment and tools

Removing the battery from an ELV-e or ELV-h with a battery outside under the floor requires:

- A bridge that attaches to the vehicle's support points (a two-post bridge, for example). These are lifts that raise the chassis by means of four arms that are positioned at the lifting or support points specified by the vehicle manufacturer.
- A lifting table to lower the battery from the vehicle chassis.

In addition, a forklift truck (or similar equipment) is used to transport any batteries removed (for the ELV listed above and for ELV-h with the battery inside the bodywork).

Transporting, removing, and managing batteries also requires special tools and personal protective equipment, in particular:

- Insulating gloves complying with standard EN 61482-1;
- Face shields complying with standard EN 61482-1;
- Protective clothing (minimum protection class 1) complying with standard EN 61482-1-2;
- Safety footwear complying with standard EN 345-1 S1.

4.2.2. Staff training

ELV center staff must be trained to remove batteries from electric and hybrid vehicles. In France, there are currently three types of training courses that provide the necessary authorization to conduct operations on ELV-e and ELV-h, including battery removal:

[27] Li-ion batteries are not currently classified as hazardous waste. Regulations may change in the future on this point (following the report of the accidentology mission on fires in WEEE dismantling centers).

- B2XL, which authorizes personnel to conduct operations in the vicinity of live bare parts;
- and B2TL, which authorize personnel to conduct operations on live batteries;
- B2VL.

In all cases, operators must be skilled in the depollution and dismantling of ELV, particularly in terms of handling heavy loads.

It should be noted that these authorizations are allocated to the individual and not to the ELV center.

According to the ELV centers consulted as part of this study, the training mentioned above is not sufficient, particularly when it comes to removing damaged and undervoltage batteries. To work on a damaged battery with undervoltage, more advanced training (adapted to the different types of damage) would be required, but this does not currently exist. In addition, working on damaged batteries would require skills in electricity, cutting, chemistry and extrication.

4.2.3. Access to a battery removal guide/procedure

Battery removal procedures vary according to vehicle manufacturer, vehicle model and vehicle condition (good or at risk).

The staff of the ELV center must have access to guides or instruction documents on the removal of batteries, depending on the situation.

There are some instructions from manufacturers on IDIS[28] . IDIS is a database of procedures for dismantling ELV, including ELV-e, ELV-h, and their batteries. It should be noted, however, that IDIS contains gaps in information on the latter two types of ELV, particularly in regards to the removal of damaged batteries. These documents only deal with cases of intact vehicles and batteries.

Some ELV centers have developed their own procedures/references for intervention, particularly in the case of damaged ELV-e and ELV-h.

4.2.4. Dedicated area for battery removal

Ideally, the dismantling area where the battery is to be deposited should be an enclosed room, separate from the thermal vehicle dismantling area and ventilated to better control the risks of fire and exposure to toxic gases. This area must be signposted.

4.2.5. Battery diagnostic capability

The ability to diagnose the SoH of the batteries removed is a prerequisite for the ELV center to be able to direct the batteries towards a second life (e.g. a possible second-hand market). Diagnostic capability requires the physical and digital tools needed to access information on the SoH of batteries, as well as the technical skills of operators to use these tools.

4.2.6. Storage of ELV-e and ELV-h at risk

Ideally, there should be a dedicated area for storing high-risk ELV-e and ELV-h.

Before the battery is removed, ELV deemed to be at risk must be stored in a dedicated area of the fleet, separate from other vehicles (ELV-e and ELV-h in good condition and thermal ELV). Each at-risk vehicle must be separated from the other vehicles by a minimum distance within

[28] Link to the IDIS website: https://www.idis2.com/

the area dedicated to these vehicles (the minimum distance is not defined and varies depending on the ELV centers questioned: from one to five meters approximately).

Other risk management solutions exist, such as storing the battery or the electrified ELV at risk:

- on a "water tank" where, in the event of a fire, the ELV or batteries are immersed;
- in a fireproof container (several fireproof technologies exist);
- in dedicated, secure warehouses away from intermediate storage areas upstream of processing.

Note: at the time of writing this report, MOBILIANS was working with the French National Institute for the Industrial Environment and Risks (Ineris) on a study of the management of batteries from end-of-life electric and hybrid vehicles by approved ELV centers, focusing in particular on regulations, risks, and best practices.

4.2.7. Storage area and dedicated containers for batteries

Battery storage will vary depending on whether the battery is destined for recycling or a second life. This differentiated storage requires knowledge of the battery's SoH and is therefore only accessible to the most advanced centers in the field of vehicle electrification.

Batteries intended for recycling must be kept in dedicated containers (see section 4.1.2.2.7)

Batteries destined for a second life will have to be stored in a dedicated building and will have to be charged and discharged regularly to prevent them from deteriorating.

4.3. Results of the national survey of all approved ELV centers

This section shows the results of the national survey of all approved ELV centers, i.e. approximately 1,700 ELV centers. The survey was launched on 15 May 2022 and closed on 5 August 2022. 411 ELV centers responded, corresponding to a response rate of 24%.

The questionnaire is presented in a separate annex to this document.

> Note: most of the questions were multiple choice; for these questions, the percentages cannot be added up (the sum of the proportions is therefore not equal to 100%).

4.3.1. Key messages

- More than half of the ELV centers responding to the survey (62%) said that they had never had to deal with the reception of an electric or hybrid vehicle;
- Of the 38% of ELV centers that said that they had already receives an electric or hybrid vehicle, the majority (75% of these centers, i.e. 28.5% of respondents) said that the delivery went smoothly thanks to their in-house knowledge;
- Nearly 80% of the ELV centers surveyed said that they had investigated or were planning to look into the technical, material, and human resources required to manage electric or hybrid vehicles;
- Nearly 55% of ELV centers surveyed said that they would not accept an electric or hybrid vehicle at their centers at present;
- Nearly 40% of the ELV centers surveyed predicted that the increase in the number of electric and hybrid vehicles will have a negative economic impact on their business, particularly because of the difficulty of managing and recovering electric traction batteries;

- Nearly 50% of ELV centers surveyed said that they currently have staff trained in removing traction batteries from electric or hybrid vehicles, and nearly 30% said that they plan to train their staff;
- Around 15% of ELV centers said that they have access to the information and/or IT tools needed to diagnose the SoH of the traction battery;
- Regarding the equipment and tools required to remove a battery:
    - 61% of the ELV centers surveyed already have a bridge that hooks onto the vehicle's support points, allowing access to the entire chassis from below (such as a two-post bridge);
    - 11% of ELV centers surveyed currently have lifting tables and an additional 9% have a similar mechanism;
    - 34% of the ELV centers surveyed already have insulated tools and an additional 30% are planning to acquire it.

4.3.2. Results

The main results of the survey are presented below by question asked. This section is structured in the same order as the questions in the questionnaire sent to ELV centers.

4.3.2.1. General feedback

- Have you ever received or been asked to receive an electric or hybrid vehicle at your center, including two/three-wheelers or quadricycles?

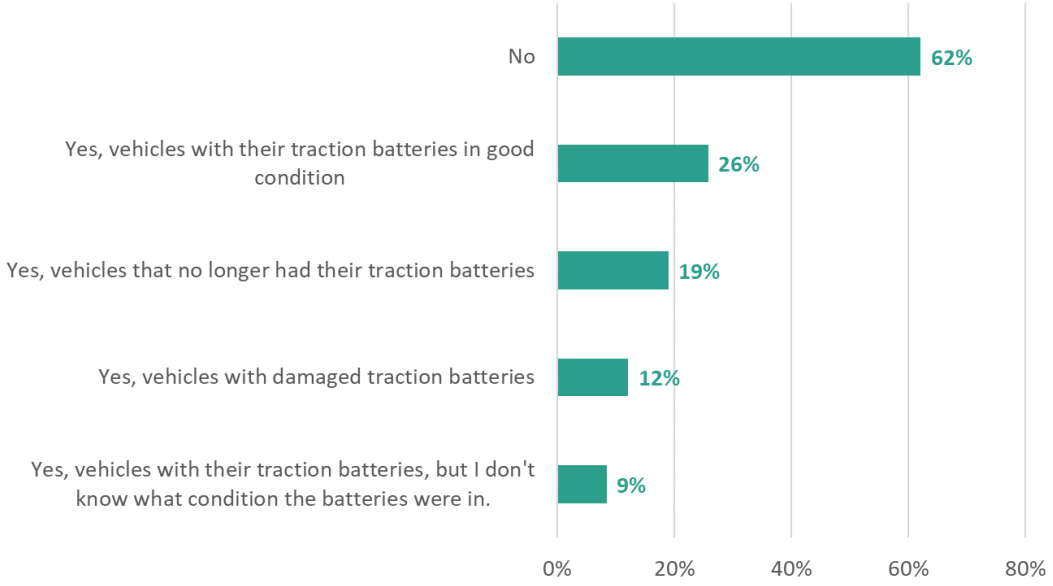


Figure 7: Response to the question "Have you ever received or been asked to receive an electric or hybrid vehicle at your center, including two- or three-wheelers or quadricycles?"

62% of ELV centers surveyed said that they had never received or had a request to receive an electric or hybrid vehicle.

The figure above shows whether the vehicles received by the remaining 38% of ELV centers had their batteries or not, and in what condition (as a reminder, several answers could be given by one center):

- 26% of vehicles approved had their traction batteries in good condition;
- 19% of vehicles approved did not have their traction batteries;
- 12% of vehicles received had damaged batteries;
- For 9%, the condition of the batteries was not known by the ELV centers.

- Generally speaking, how did the reception of these vehicles go?

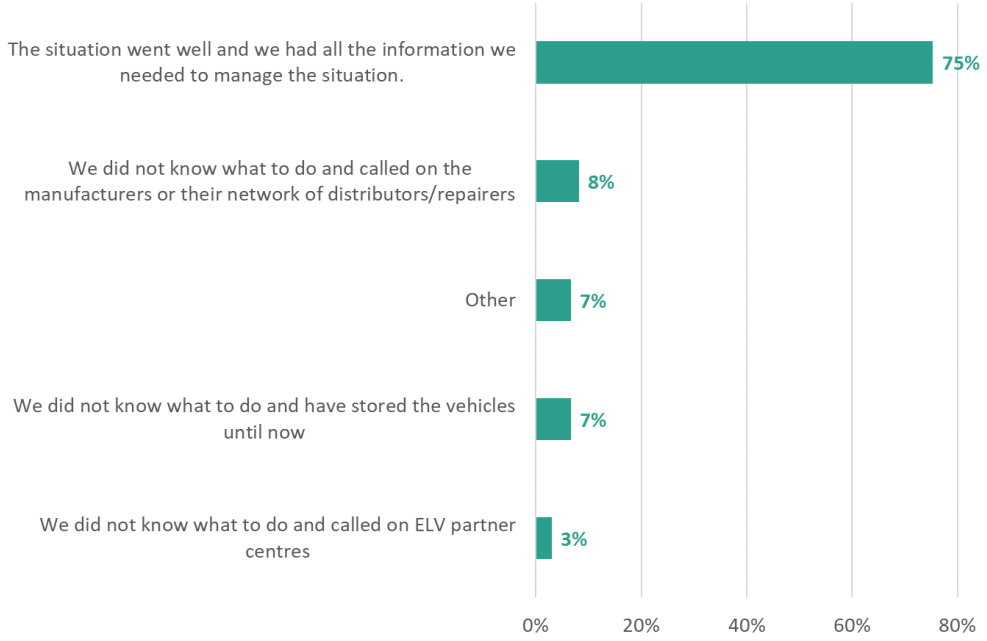


Figure 8: Response to the question "Generally speaking, how did the acceptance of these vehicles go?"

Of the ELV centers surveyed that had received an electric or hybrid vehicle, 75% said that the reception of the vehicles went smoothly and that they had the information they needed to manage the situation.

The figure above shows the other answers given.

- Would you be willing to take delivery of an electric or hybrid vehicle at your center?

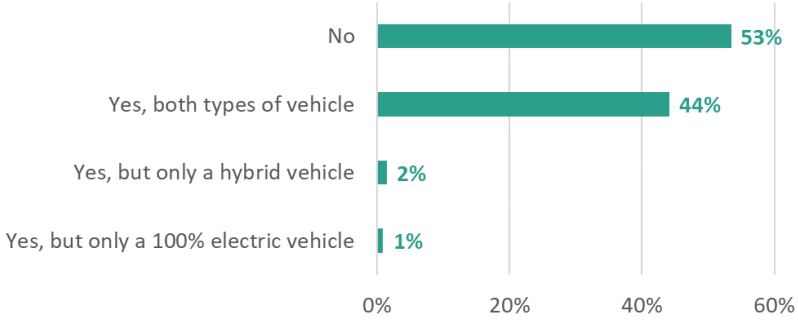


Figure 9: Response to the question "Would you be willing to receive an electric or hybrid vehicle at your center?"

53% of ELV centers surveyed said they would not accept an electric or hybrid vehicle at their centers.

A cross-analysis of this response with the respondents' scope of activity (whether or not they dismantle parts for reuse) revealed that:

- 80% of all ELV centers that do not dismantle parts for reuse answered "no" to this question;
- Of the total number of ELV centers that answered "no", half do not dismantle parts for reuse.

- Generally speaking, do you think you have the necessary information to receive the following vehicles at your center?

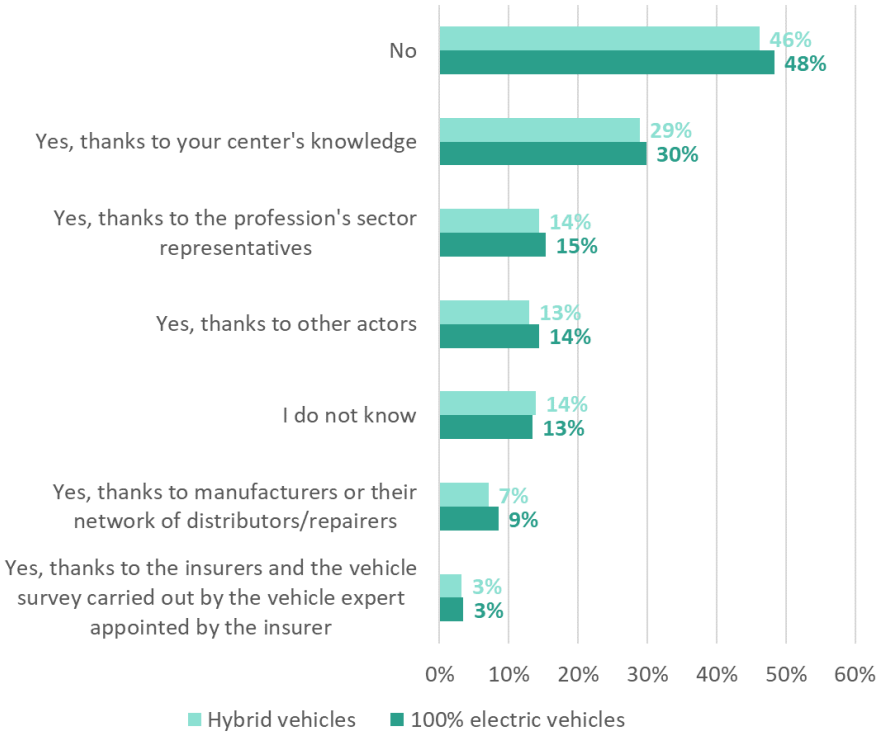


Figure 10: Response to the question "In general, do you think you have the necessary information to receive the following vehicles at your center?"

Some 47% of ELV centers surveyed said they did not have the information they needed to receive an electric or hybrid vehicle at their centers. On the other hand, around 40% of respondents indicated that they have this information, mainly

thanks to their internal knowledge (30%). The figure above also shows other possible sources of information for ELV centers.

Respondents who said "Yes, thanks to other players", and who specified the source, most often cited the INDRA network.

Respondents who said "Yes, thanks to manufacturers" most often cited RENAULT for 100% electric vehicles and TOYOTA for hybrid vehicles.

In addition, a cross-analysis of the response of the ELV centers that answered "No" to the illustrated question and the scope of the respondents' activity (dismantling of parts for reuse or not) revealed the following:

- 80% of all ELV centers that do not dismantle parts for re-use answered "no" to this question;
- just under half of the centers indicating "No" do not dismantle parts for reuse. It can be deduced that there is no correlation between the negative response and the scope of activity.

- Have you found out about the technical, material, human and other resources required to take charge of the following vehicles and their traction batteries?

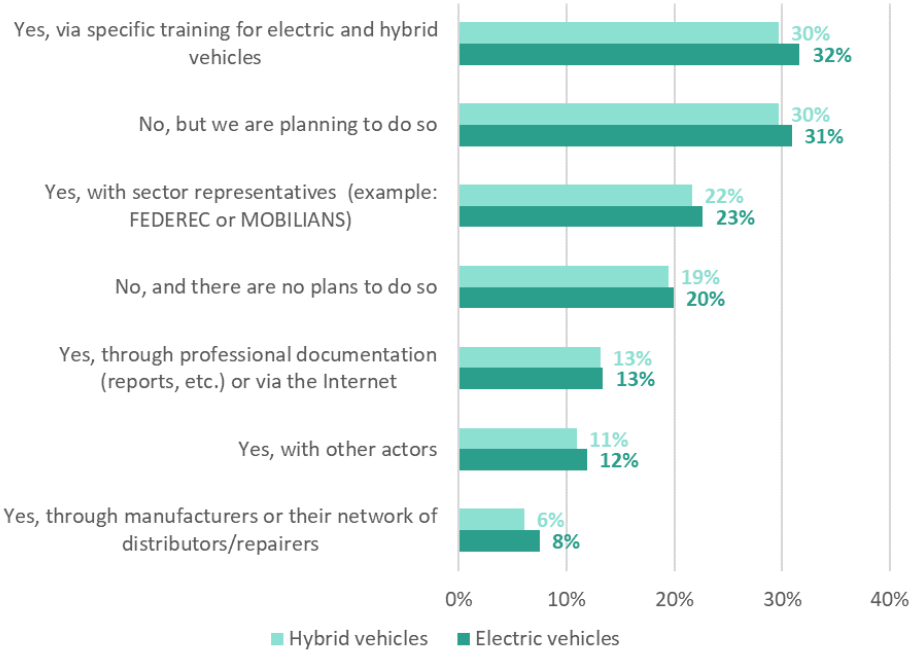


Figure 11: Response to the question "Have you found out about the technical, material and human resources, etc. required to take charge of the following vehicles and their traction batteries?"

Some 31% of the ELV centers surveyed said they had enquired about the technical, material and human resources required to manage electric or hybrid vehicles. A similar percentage of ELV centers indicated that they had not yet done so but were planning to do so. On the other hand, around 20% said that they had not looked into the matter and had no plans to do so in the future.

Respondents who indicated "Yes, from other players", and who specified the source, most often cited the INDRA network. Respondents who indicated "Yes,

from manufacturers" most often cited RENAULT for 100% electric vehicles and TOYOTA for hybrid vehicles.

In addition, a cross-analysis of the ELV centers that answered "No, and there are no plans to do so" to this question and the respondents' scope of activity (dismantling of parts for reuse or not) revealed that

- 30% of all ELV centers that do not dismantle parts for reuse answered "No, and there are no plans to do so" to this question;
- Just over half of the centers indicating "No, and there are no plans to do so" have a dismantling activity for reused parts.

- What impact do you think the increase in the number of electric and hybrid vehicles will have on the activity of ELV centers?

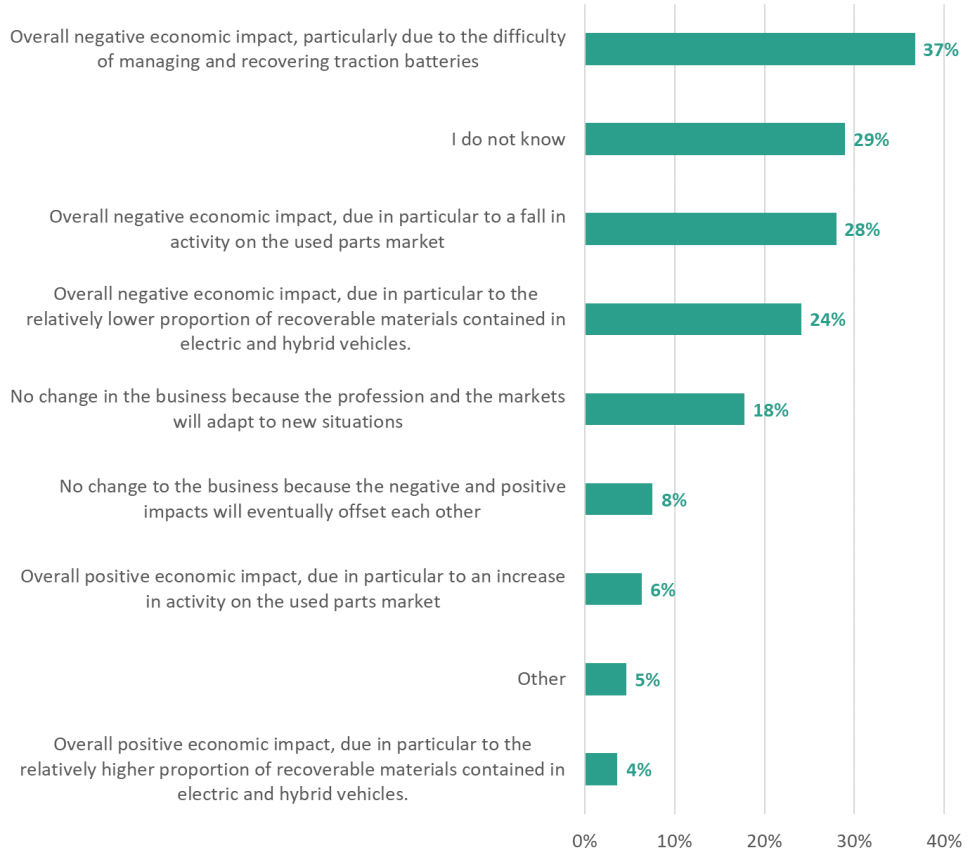


Figure 12: Response to the question "In your opinion, what impact would the increase in the number of electric and hybrid vehicles have on the activity of ELV centers?"

As a reminder, several answers could be given by a center.

Concerning the economic impact of the increase in the number of electric and hybrid vehicles on the activity of ELV centers:

- 37% of the ELV centers surveyed anticipate a negative economic impact overall, due in particular to difficulties in managing and recovering traction batteries;
- 18% of ELV centers surveyed said that they did not anticipate any change in the activity of their centers, as they expect the business and markets to adapt to the new situation;
- 6% of ELV centers surveyed anticipate positive economic benefits overall, mainly as a result of an increase in the second-hand parts market.

The other responses are shown in the figure above.

4.3.2.2. Vehicle reception

100% ELECTRIC VEHICLES

- Have you already received the following 100% electric vehicles at your center?

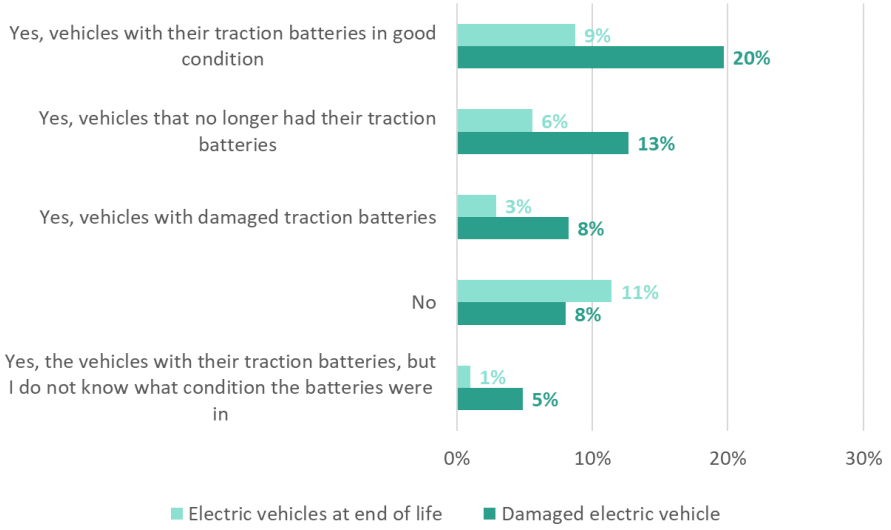


Figure 13: Response to the question "Have you already received the following 100% electric vehicles at your center?"

In the case of ELV centers that have received 100% electric vehicles, these are usually vehicles that have been involved in accidents:

- 20% of these respondents said that they had received 100% electric vehicles in accidents with their traction batteries in good condition;
- 13% of these respondents said that they had received 100% electric vehicles in accidents without their traction batteries;
- 8% of these respondents said that they had received 100% electric vehicles in accidents with damaged traction batteries.

As for the 100% electric vehicles approved because they have reached the end of their life:

- 9% of these respondents indicated that they had received 100% electric vehicles at the end of their life with their traction batteries in good condition;
- 6% of these respondents said that they had received 100% electric vehicles at the end of their life without their traction batteries;
- 3% of these respondents indicated that they had received 100% electric vehicles at the end of their life with damaged traction batteries.

The other responses are shown in the figure above.

- Were any of the electric vehicles approved two/three-wheelers or quadricycles?

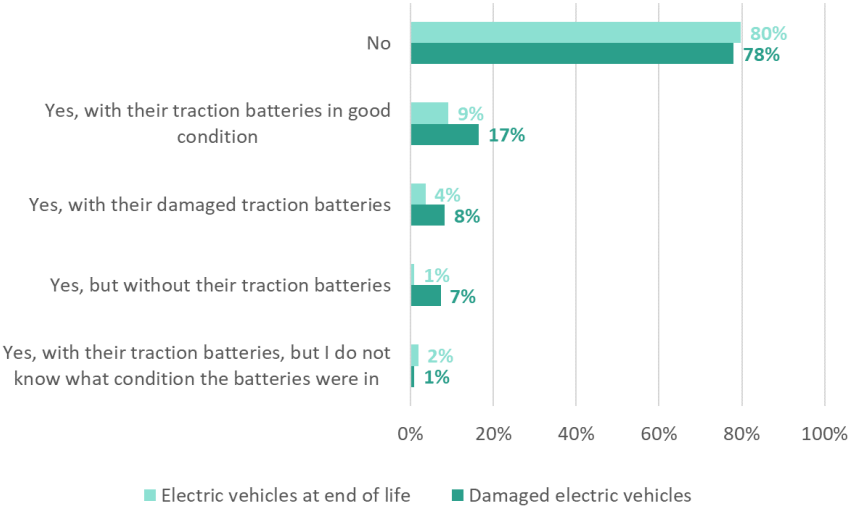


Figure 14: Response to the question "Were any of the electric vehicles approved two/three-wheelers or quadricycles?"

Around 80% of ELV centers that had received 100% electric vehicles indicated that they had not received 100% electric two/three-wheel or quadricycle vehicles, either involved in accidents or at the end of their life.

On the other hand:

- 17% of ELV centers that have received 100% electric vehicles say they have received 100% electric two/three-wheeled vehicles or quadricycles that have been involved in accidents, mainly with their traction batteries in good condition;
- 9% of ELV centers that have received 100% electric vehicles say they have received 100% electric two/three-wheel vehicles or quadricycles at the end of their life, mainly with their traction batteries in good condition.

The other responses are shown in the figure above.

- Have you already processed the electric vehicles you have received at your center?

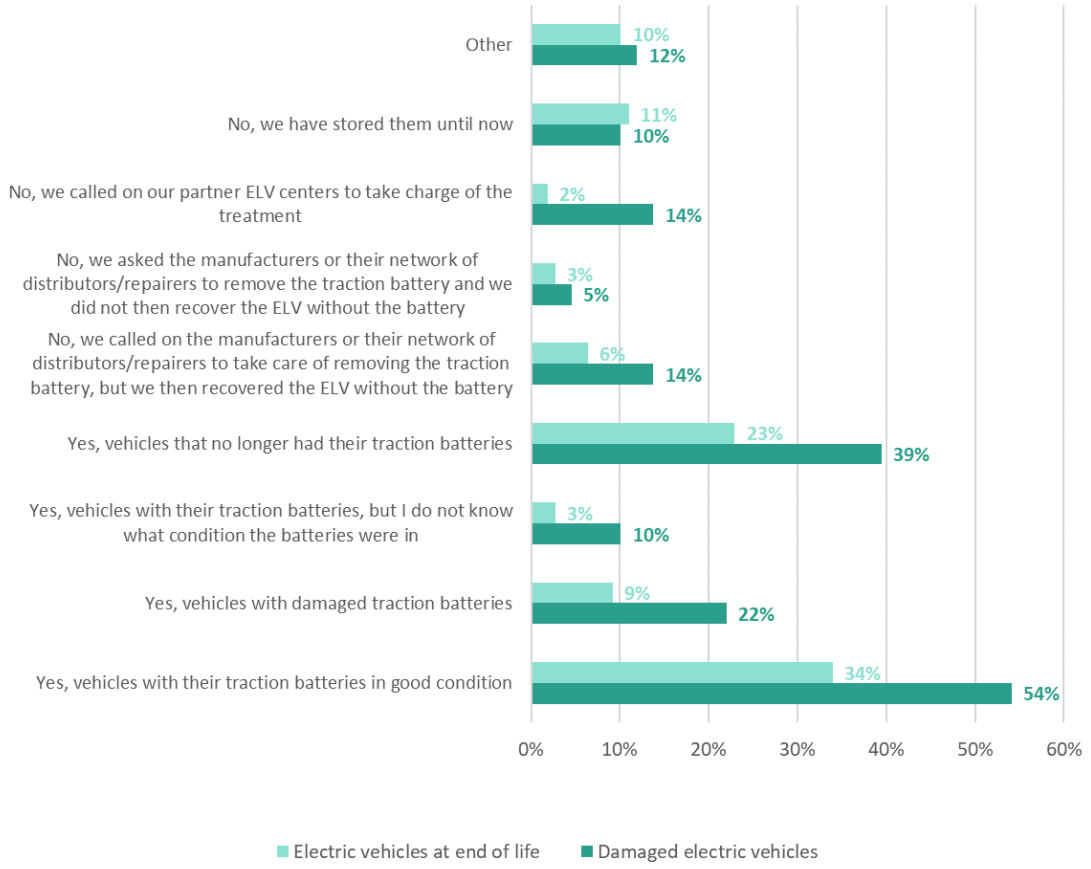


Figure 15: Response to the question "Have you already processed the electric vehicles you have received at your center?"

Among the ELV centers that have received 100% electric vehicles that have been involved in accidents:

- 54% said they had treated them with their traction battery in good condition;
- 39% said they had treated them without their traction battery;
- 22% said they had treated them with their damaged battery.

Among the ELV centers that received 100% electric vehicles at the end of their life:

- 34% said they had treated them with their traction battery in good condition;
- 23% said they had treated them without their traction battery;
- 9% said they had treated them with their damaged battery.

Some ELV centers say they have received 100% electric vehicles that have been involved in accidents but have not processed them. Among the ELV centers that have received 100% electric vehicles:

- 14% said they had used the services of partner ELV centers;
- 14% said they used the services of manufacturers or their dealer/repair network;
- 10% say they have stored them until now.

Some centers that indicated "Other" in their responses reported that these 100% electric vehicles, which they had received but not processed, were sold as is for export.

The other responses are shown in the figure above.

HYBRID VEHICLES

- Have you already received the following hybrid vehicles at your center?

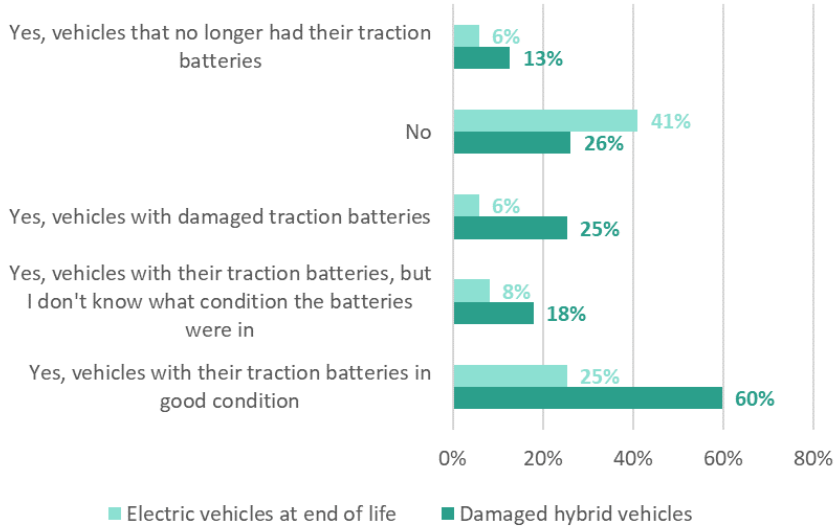


Figure 16: Response to the question "Have you already received the following hybrid vehicles at your center?"

For ELV centers that have received hybrid vehicles, these are usually vehicles that have been involved in accidents:

- 60% of these respondents said that they had received hybrid vehicles in accidents with their traction batteries in good condition;
- 26% of these respondents said that they had received hybrid vehicles in accidents with damaged batteries;
- 13% of these respondents said that they had received hybrid vehicles in accidents without their traction batteries.

As for hybrid vehicles that are at the end of their life:

- 25% of these respondents said that they had received end-of-life hybrid vehicles with their traction batteries in good condition;
- 6% of these respondents indicated that they had received end-of-life hybrid vehicles without their traction batteries;
- 6% of these respondents indicated that they had received end-of-life hybrid vehicles with damaged batteries.

The other responses are shown in the figure above.

- Were any of the hybrid vehicles approved two/three-wheelers or quadricycles?

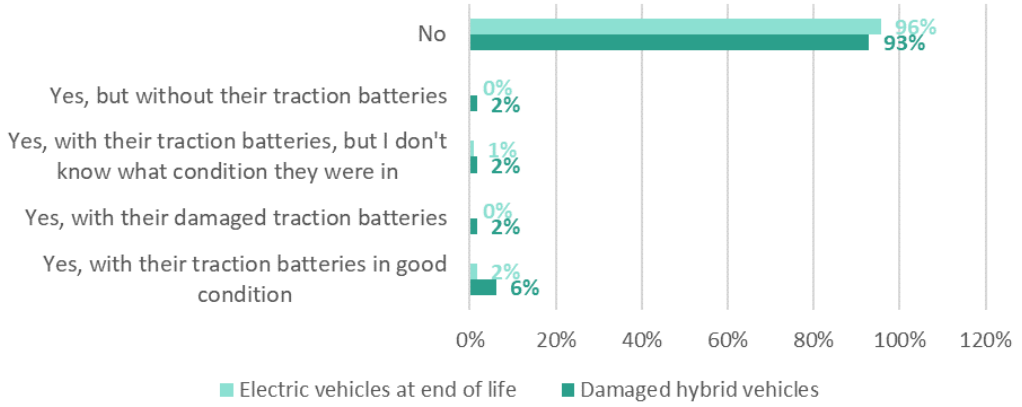


Figure 17: Response to the question "Were any of these approved hybrid vehicles two- or three-wheelers or quadricycles?"

Around 95% of ELV centers that had received hybrid vehicles indicated that they had not received any two/three-wheel or quadricycle hybrid vehicles, either involved in accidents or at the end of their life.

The other responses are shown in the figure above.

- Have you already treated the hybrid vehicles you have received at your center?

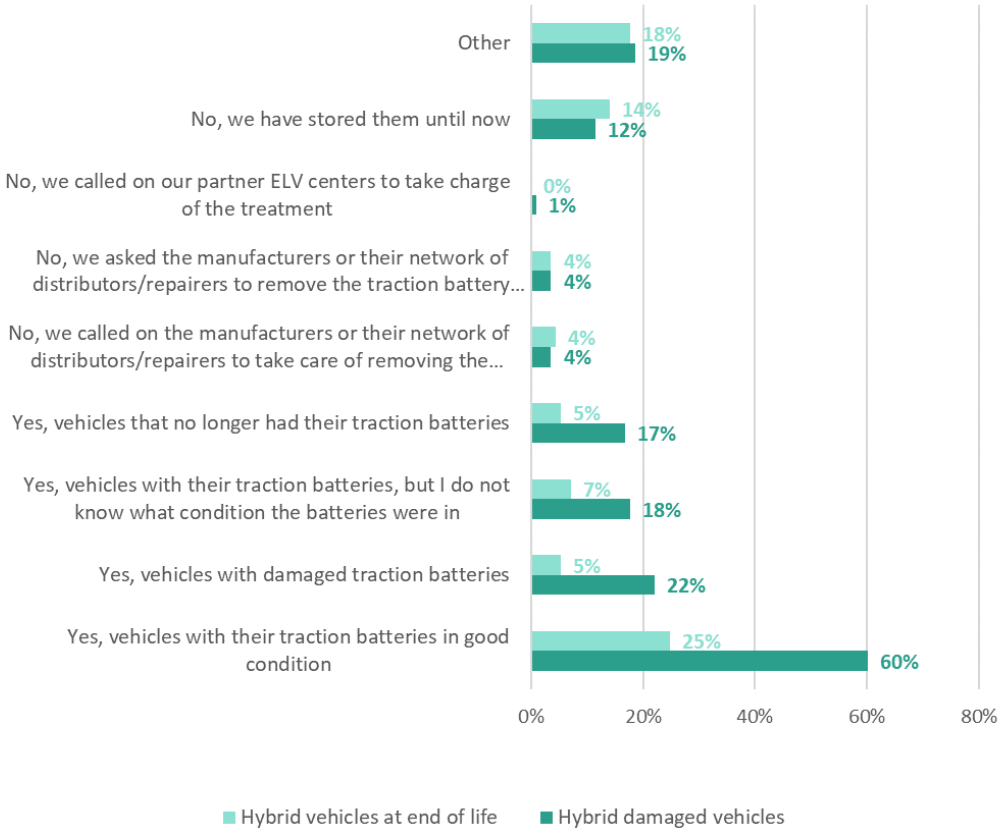


Figure 18: Response to the question "Have you ever treated the hybrid vehicles you have received at your center?"

With regard to the treatment of vehicles received, some ELV centers have received hybrid vehicles that have been involved in accidents:

- 60% of these respondents said that they had treated them with their traction battery in good condition;
- 22% said they had treated them with their damaged battery.

As for end-of-life hybrid vehicles, 25% of these respondents said that they had treated them with their traction battery in good condition.

Some ELV centers say they have received hybrid vehicles but have not processed them. Most of these centers say that they have stored vehicles at the end of their life or involved in accidents until now.

Some centers that indicated "Other" in their responses reported that these hybrid vehicles, which they had received but not treated, had been sold as is for export.

The other responses are shown in the figure above.

4.3.2.3. Removing the traction battery

- Have you disposed of your batteries?

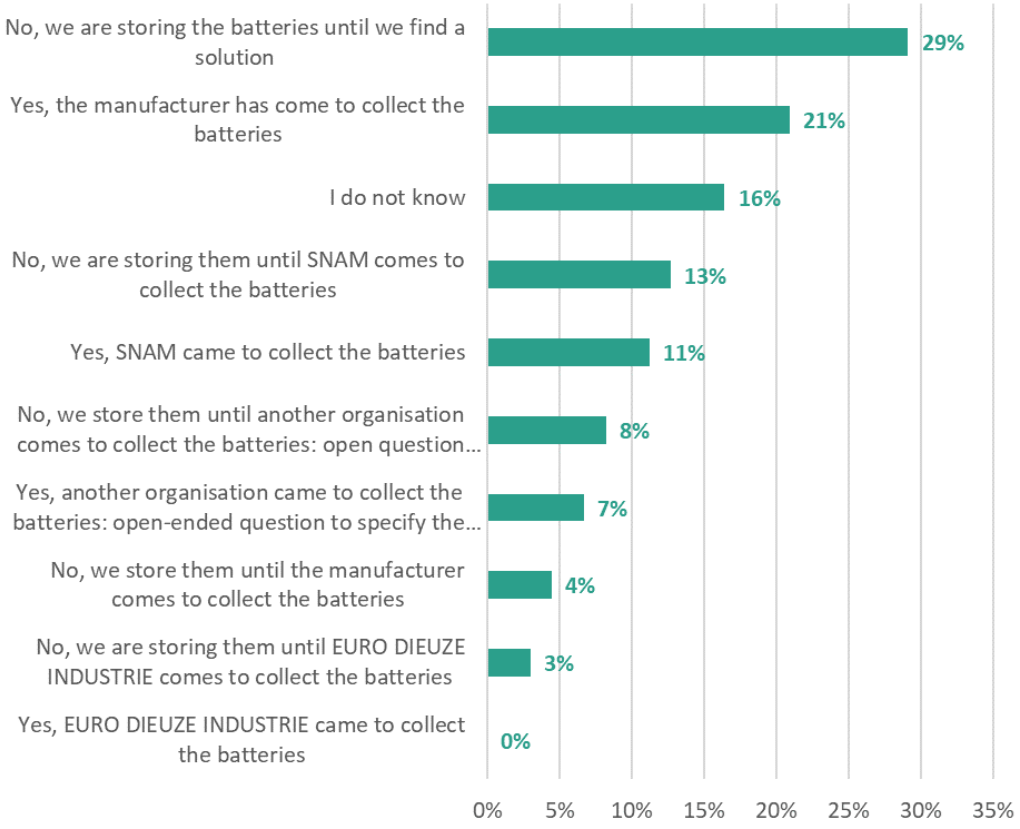


Figure 19: Response to the question "Have you disposed of your batteries?"

Disposal and management of batteries:

- 29% of centers that have received electric or hybrid vehicles say they are storing the batteries until a solution is found;
- 21% of centers that have received electric or hybrid vehicles say that the manufacturers have come to collect the batteries.

The other responses are shown in the figure above.

100% ELECTRIC VEHICLES

- Do you think you have the resources and skills to remove (dismantle) the traction battery of the following 100% electric vehicles?

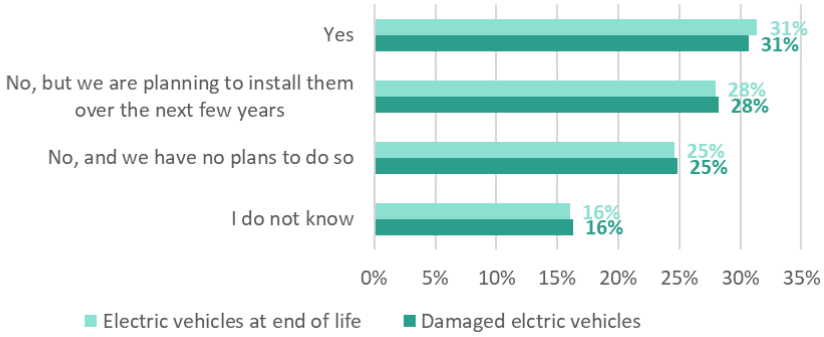


Figure 20: Response to the question "Do you think you have the ressources and skills to remove (dismantle) the traction battery of the following 100% electric vehicles?"

31% of ELV centers surveyed say they have the resources and skills to dispose of traction batteries from 100% electric vehicles at the end of their life or involved in accidents. 28% of the ELV centers surveyed said they were going to equip themselves with these resources and skills. On the other hand, 25% of the ELV centers surveyed said they did not have these resources and skills and had no plans to acquire them.

- Do you think you have the resources and skills to manage the following 100% electric vehicles once their traction battery has been removed (dismantled)?

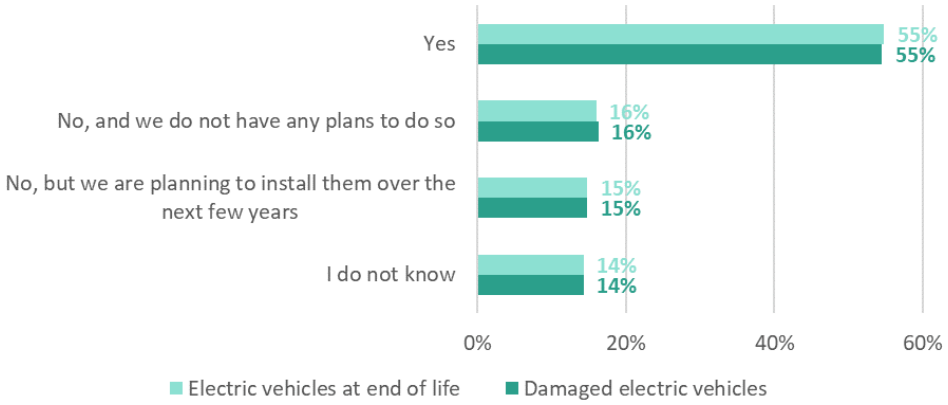


Figure 21: Answer to the question "Do you think you have the resources and skills to manage the following 100% electric vehicles once their traction battery has been removed (dismantled)?"

The majority of ELV centers state that they currently have (55%) or plan to acquire (15%) the resources and skills to manage 100% electric vehicles once their traction

battery has been removed, regardless of whether the vehicle has been involved in an accident or is at the end of its life.

On the other hand, 16% say they do not have these resources and skills and have no plans to acquire them.

HYBRID VEHICLES

- Do you think you have the resources and skills to remove (dismantle) the traction battery of the following hybrid vehicles?

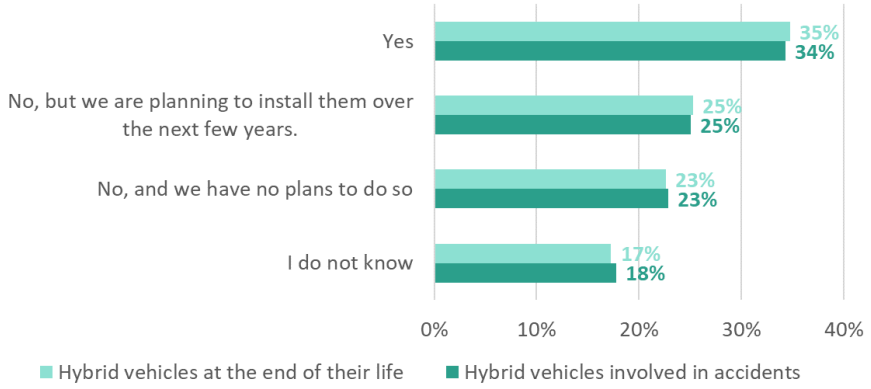


Figure 22: Response to the question "Do you think you have the resources and skills to remove (dismantle) the traction battery of the following hybrid vehicles?"

35% of ELV centers say they currently have the resources and skills to remove traction batteries from hybrid vehicles at the end of their life or involved in accidents. 25% of ELV centers say they are planning to acquire these facilities. On the other hand, 23% said they did not have the resources and skills and had no plans to acquire them.

- Do you think you have the resources and skills to manage the following hybrid vehicles once their traction batteries have been removed (dismantled)?

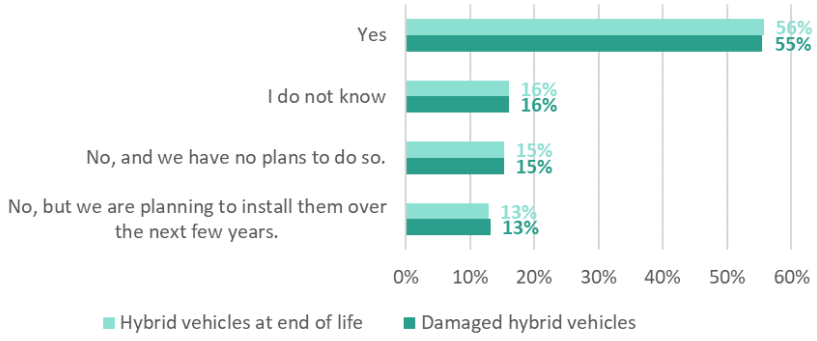


Figure 23: Response to the question "Do you think you have the resources and skills to manage the following hybrid vehicles once their traction batteries have been removed?"

55% of ELV centers say they currently have the resources and skills to remove traction batteries from hybrid vehicles at the end of their life or involved in accidents. 13% of ELV centers say they are planning to acquire these facilities. On

the other hand, 23% said they did not have these resources and skills and had no plans to acquire them.

4.3.2.4. Access to a guide/procedure for removing traction batteries

- Do you use the IDIS database?

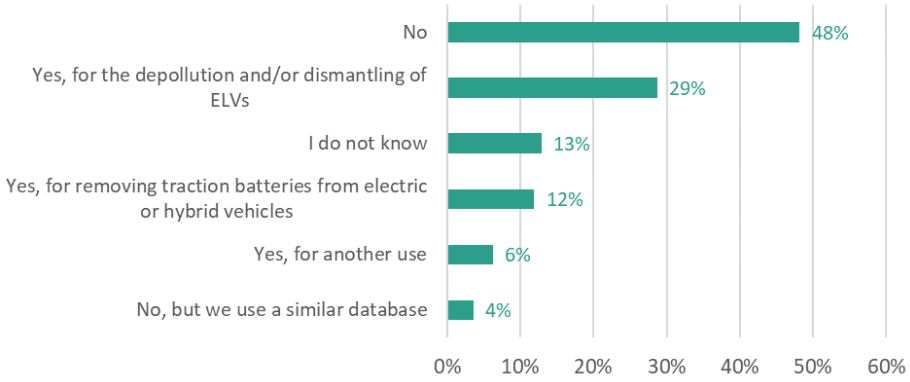


Figure 24: Response to the question "Do you use the IDIS database?"

Nearly half of ELV centers say they do not use the IDIS database.
Centers indicating that they use the IDIS database:

- 29% do so for the depollution and/or dismantling of electric or hybrid vehicles;
- 12% do so to remove traction batteries.

Some respondents mentioned similar databases: Opisto, TIS, DIAGDOC, Euro Rescue and ADAC.

The other responses are shown in the figure above.

- Do you have access to a procedure for removing the following traction batteries?

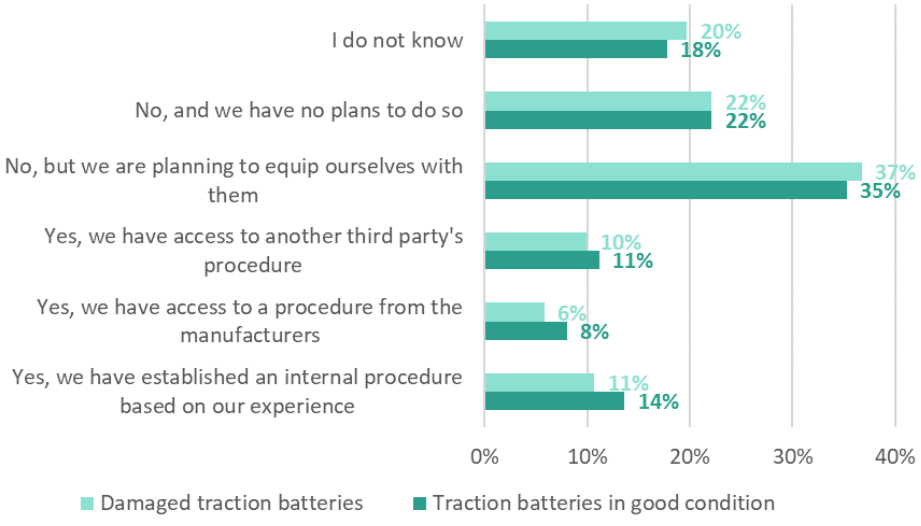


Figure 25: Response to the question "Do you have access to a procedure for removing the following traction batteries?"

Approximately 36% of ELV centers indicated that they do not currently have access to a guide or procedure for the removal of traction batteries, regardless of whether the ELV are damaged or in good condition, but that they plan to acquire access. On the other hand, 22% reported that they do not currently have access and have no plans to do so.

In addition, a minority of ELV centers indicate that they have access to a procedure for the removal of damaged or undamaged batteries:

- around 12% have established this procedure on the basis of internal experience;
- approximately 11% have access to a third-party procedure (the INDRA network is often cited by respondents who specified their answer);
- Around 7% have access to a procedure provided by the manufacturers.

The other responses are shown in the figure above.

4.3.2.5. Traction battery status diagnostic capability

- Do you have the information and/or IT tools needed to diagnose the SoH of the traction battery?

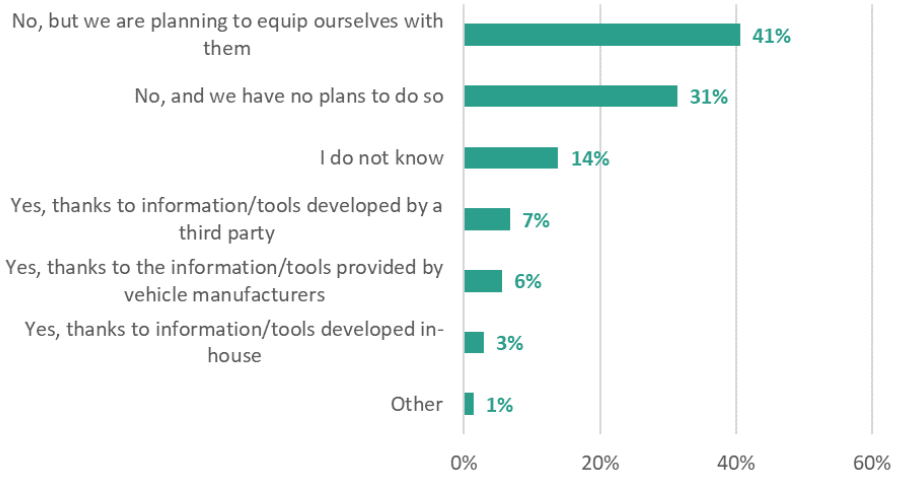


Figure 26: Response to the question "Do you have the information and/or IT tools needed to diagnose the SoH of the traction battery?"

Around 41% of the ELV centers indicated that they do not currently have the information and/or IT tools needed to diagnose the SoH of the traction battery, but that they plan to acquire them. On the other hand, 31% said that they do not currently have access and do not plan to acquire them. In addition, around 15% of ELV centers say they have access to the information and/or IT tools needed to diagnose the SoH of the traction battery:

- around 7% thanks to information and/or tools developed by a third party (the INDRA network is often cited by respondents who gave a specific answer);
- around 6% thanks to carmakers.

The other responses are shown in the figure above.

4.3.2.6. Staff training

- Are your staff trained in removing traction batteries from electric or hybrid vehicles?

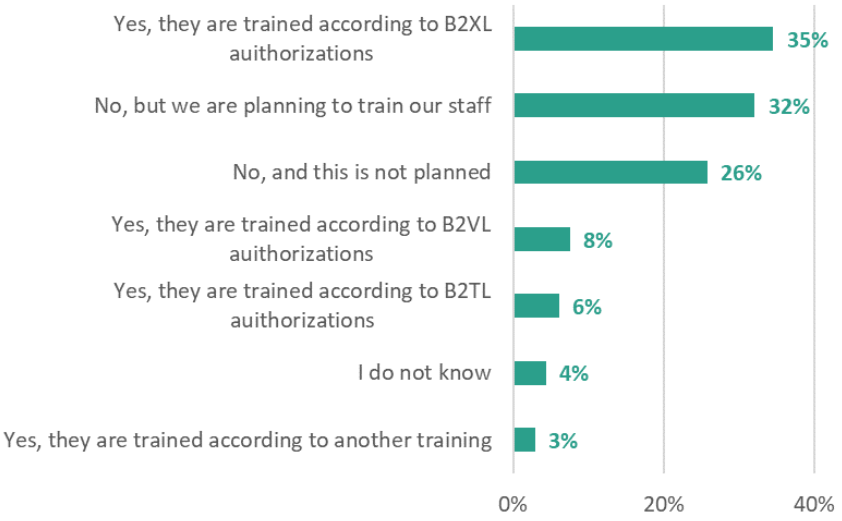


Figure 27: Response to the question "Are your staff trained in removing traction batteries from electric or hybrid vehicles?"

52% of ELV centers say they currently have staff trained in removing traction batteries from electric or hybrid vehicles. The majority of these centers indicate that:

- They are trained according to B2XL authorizations;
- The training is fairly recent: on average, training courses started in 2019.

Regardless of the type of training, on average, ELV centers with staff trained in battery removal report:

- having two people trained;
- having incurred a training cost of around EUR 1,100 per person trained.

32% of ELV centers say they plan to train their staff.

On the other hand, 32% said they had no plans to train their staff in removing traction batteries.

The other responses are shown in the figure above.

4.3.2.7. Equipment and tools

BRIDGE

- Does your ELV center have a bridge that hooks onto the vehicle's support points, allowing access to the entire chassis from below (a two-post bridge, for example)?

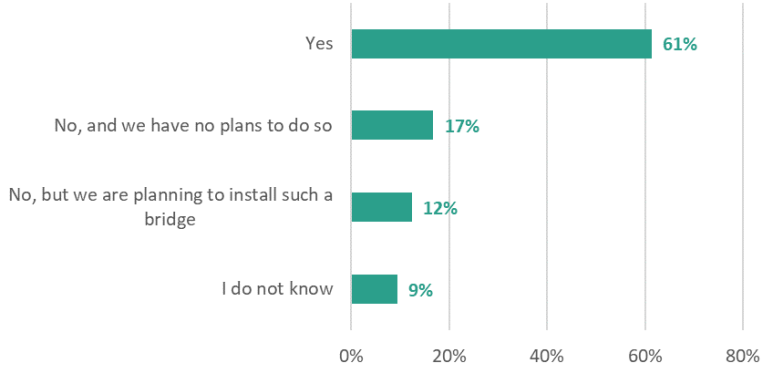


Figure 28: Answer to the question "Does your ELV center have a bridge that hooks onto the vehicle's support points, allowing access to the entire chassis from below (a two-post bridge, for example)?"

61% of ELV centers already have a bridge that attaches to the vehicle's support points, allowing access to the entire chassis from below (such as a two-post bridge). On average, there are two bridges per ELV center.

12% of ELV centers are planning to install them.

On the other hand, 12% of ELV centers have no plans to acquire such equipment.

The other responses are shown in the figure above.

LIFT TABLE

- Does your ELV center have a lifting table or other mechanism that allows the traction battery to be placed on once it has been separated from the chassis?

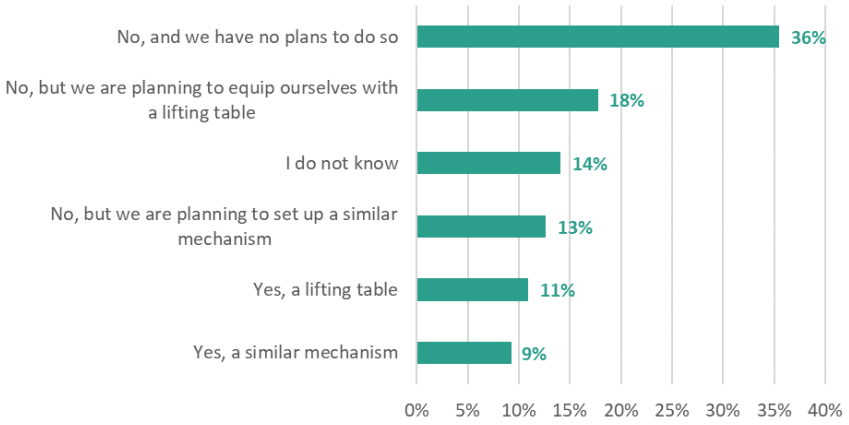


Figure 29: Answer to the question "Is your ELV center equipped with a lifting table or other mechanism to allow the traction battery to be placed on once it has been separated from the chassis?"

11% of ELV centers currently have lifting tables and 9% have a similar mechanism. On average, they have one per ELV center.

In addition, around 30% of centers are planning to acquire a lifting table or similar mechanism. On the other hand, 36% of centers do not have or do not plan to acquire a lifting table or similar mechanism.

The other responses are shown in the figure above.

INSULATED TOOLS

- Does your ELV center have insulated tools for working on electrified equipment?

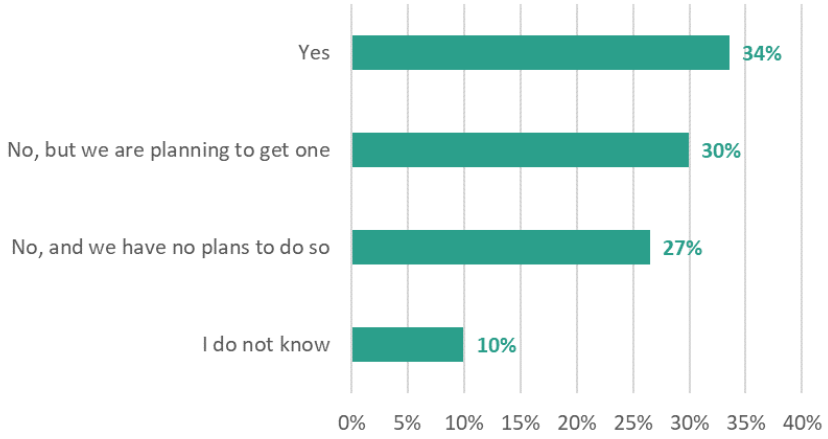


Figure 30: Answer to the question "Does your ELV center have insulated tools for work on electrified equipment?"

34% of ELV centers already have insulated tools and 30% are planning to acquire them. However, 27% have no plans to do so.

The other responses are shown in the figure above.

4.3.2.8. Storage of ELV and traction batteries

- How much storage space do you currently have for thermal, electric and hybrid ELV (ELV before treatment and excluding used vehicles)?

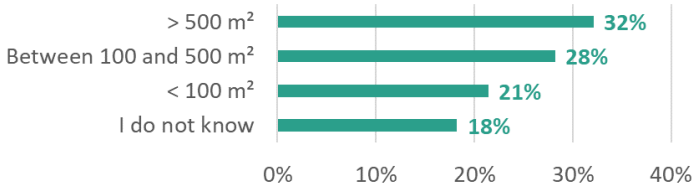


Figure 31: Response to the question "How much storage space do you currently have for thermal, electric and hybrid ELV (ELV before treatment and excluding used vehicles)?"

60% of ELV centers reported having 100 m^2 or more of storage space for thermal, electric and hybrid ELV:

- 32% have more than 500 m^2;
- 28% have between 100 and 500 m^2.

The other responses are shown in the figure above.

- Do you already store combustion, electric and hybrid vehicles separately at your ELV center?

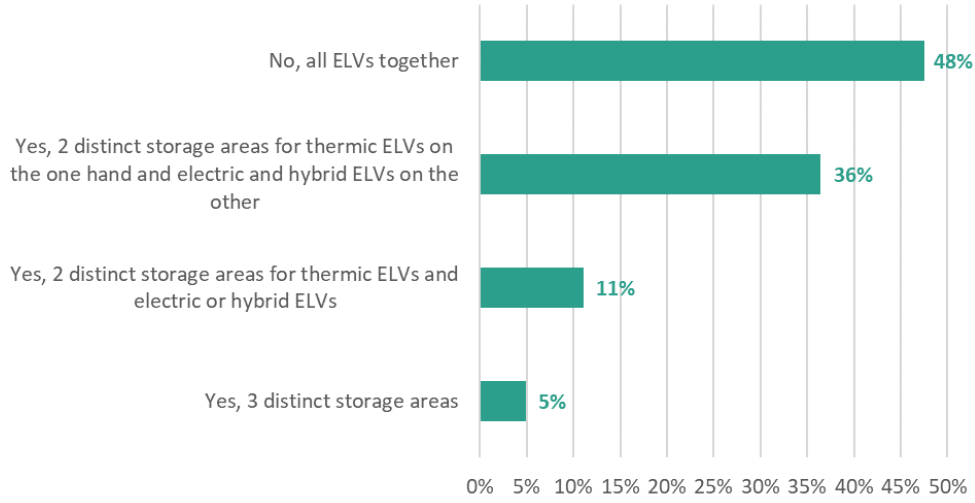


Figure 32: Response to the question "Do you already store combustion, electric and hybrid vehicles separately at your ELV center?"

Nearly half of the ELV centers that have already received 100% electric or hybrid ELV store them without distinction (between thermal, electric or hybrid).

The other responses are shown in the figure above.

5. Phase 3 - Assessment of the expected volume of electric and hybrid end-of-life vehicles in the next 5, 10, 15 and 20 years

The objectives of this chapter are as follows:

- estimate changes in the size of the vehicle fleets at different timescales for private cars, light commercial vehicles and motorized two-, three- and four-wheelers, as well as the composition of these vehicle fleets by type of motorization;
- assess the share of the corresponding volumes of end-of-life vehicles in these different timeframes, identifying in particular the share of electric and hybrid end-of-life vehicles.

To enable the ELV processing sector to prepare itself in the best possible way for these changes in future flows, both in terms of volumes and composition/type, it is essential to have a clear vision prior to the evolution of the corresponding vehicle fleet. These are therefore the stated objectives of the forward-looking approach described below.

5.1. Projected volume of end-of-life vehicles

5.1.1. Light vehicles, the main parameter of impact

Firstly, the work will focus on light vehicles (LV) (private vehicles (PV) and light commercial vehicles (LCV)) as the main factor in the impact of the electrification of mobility:

- The volume of LV on the road is much greater than the volume of two-, three- and four-wheelers, by a factor of almost ten in France and around seven in Europe;
- The impact is all the greater for much larger vehicles, with many more components and a high technological content;
- Unlike the two-, three- and four-wheelers sector, regulations have been in place for a long time (EURO standards in particular) and are rapidly moving towards increasingly stringent requirements.

A good understanding of the challenges posed by the electrification of the LV fleet and a forward-looking view of the volumes of electrified ELV in the future are therefore all that is needed for the treatment sector to prepare itself and size its tools and facilities accordingly.

5.1.1.1. Overview of the approach

The model developed by BIPE-BDO for the WAPO (*World Automotive Powertrain Outlook*) is demand-based: it is based on the rational choice made by LV buyers according to the total *cost of ownership* (TCO) of the vehicle. This choice is also subject to various types of constraint, such as European and national regulations, tax instruments and the compatibility of supply with mobility needs. The choice is made on the basis of cost, according to different user clusters distributed over different uses (private or professional, different levels of daily and annual mileage). Aggregating these choices gives us the engine mix—also known as *powertrain*—for new vehicles from 2020 to 2040.

The evolution of the vehicle fleet over the long term is then calculated on the basis of the macroeconomic context of different scenarios. These scenarios are differentiated by the contrasting intensities of economic growth and the extent to which environmental issues are considered (through greater or lesser regulatory intensity). In the case of France, the two scenarios selected were those considered the most likely for the European zone, and commonly referred to as *Green Growth* and *Green Constraint* by the industry (see details below).

5.1.1.2. Details on the granularity of the WAPO model

The model includes a fine granularity of available powertrains (including electrics and all hybrids) and vehicle segments (seven Private vehicles (PV) segments, four light commercial vehicles (LCV) segments): see tables below. ELV volumes will therefore also be broken down by car and light commercial vehicle category.

Segment	Description	Example
[PV]		
A	Extra Small Car	Smart, Renault Twingo
B_Low	Small Car	Peugeot 208, Renault Clio
B_High	Compact SUV	Peugeot 2008, Renault Captur
C_Low	Medium Car	Peugeot 308, Renault Mégane
C_High	Medium SUV	Peugeot 3008, Renault Scénic
D_Low	Large Car	Peugeot 508, Renault Talisman
D_High	Large SUV	Peugeot 807, Renault Koleos
[LCV]		
F1	Micro Van	Peugeot Bipper, Renault Kangoo
K1	Medium Van	Peugeot Expert, Renault Trafic
K2	Heavy Van	Peugeot Boxer, Renault Master
PU	Pick-Up Truck	VW Amarok…

Table 4: Segmentation of the WAPO model

Motorization	Description
microHEV	Micro Hybrid Electric Vehicle
MHEV	Mild Hybrid Electric Vehicle
HEV	Hybrid Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
EREV (being phased out)	Extended Range EV
BEV	Battery Electric Vehicle
Fuel Cell	Fuel Cell Vehicle
PFCV	Fuel Cell Plug-In Hybrid

Table 5: Names of the electrified powertrains included in the WAPO model

5.1.1.3. Volume scenarios

As previously indicated, two distinct modulation scenarios will be used throughout the study in the projection phases: *Green Constraint* (GC) and *Green Growth* (GG).

At the first level, they are both linked to a high level of environmental regulation and differ mainly in terms of economic growth, which is more favorable in the case of *Green Growth*:

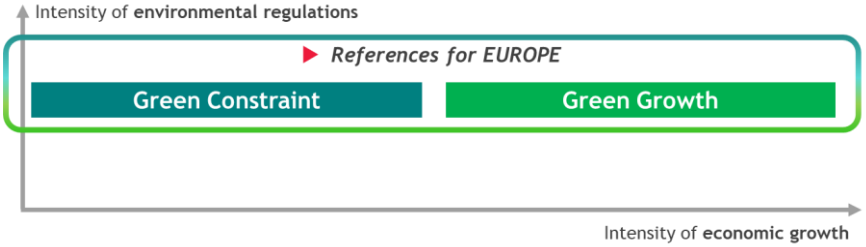


Figure 33: Simplified view of modulation scenarios

In reality, in the implementation of the WAPO model, the cost assumptions on which each case is based are quite different:

- energy prices, particularly fossil fuels (GG > GC) vs. low-carbon or decarbonized energy (GG < GC);
- the cost of electrification components, especially batteries (EUR/kWh), will be more favorable in the *Green Growth* context by 2040.

The key point to remember is that the electrification dynamic of the *Green Growth* scenario will only be possible thanks to the significant cost reduction forecasts in the model's input assumptions, in particular due to the effects of scale on electric powertrain components: this will require major efforts, within the favorable framework announced. If this drastic cost reduction is not achieved—particularly for batteries—sales of electric vehicles and hydrogen vehicles will be significantly lower, with the *Green Constraint* scenario becoming the central projection scenario.

The advantage of using two modulation scenarios for the projections is clear: in addition to the numerical results, it provides a scope and room for reflection on possible futures.

5.1.1.4. The European "Fit For 55" framework

Announced in July 2021, the European Commission's "Fit For 55" package includes a number of specific proposals for light vehicles, including the intention to ban all combustion engines as of 2035.

The WAPO powertrain availability matrix has therefore been brought into line with this major change for Europe: in the central shooting sales projections, used as a basis for this study, only zero-emission ZEV vehicles (EVs with batteries and fuel cells) will be available for purchase as of 2035.

5.1.1.5. Determination of ELV volume

This chapter describes the targeted ELV approach and the links between the various stages.

The figure below gives a consolidated overview of the various modelling and calculation components required to obtain the flow of ELV (identified by segment and type of powertrain), from which the flow of electrified ELV relevant to the study was isolated.

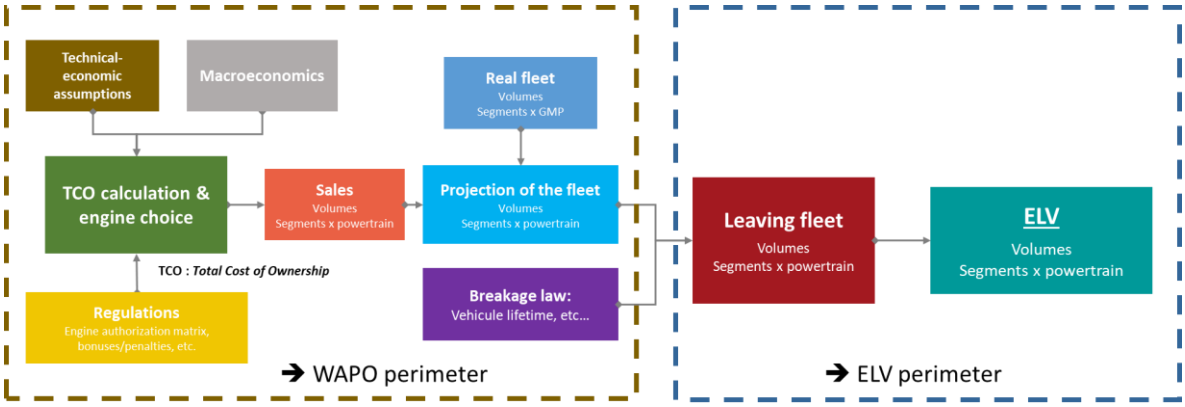


Figure 34: Diagram of WAPO modelling coupled with the ELV brick

From the point of view of the treatment process, the following diagram summarizes the various intermediate levels of flow separation between the vehicle fleet and the ELV, which are explained underneath:

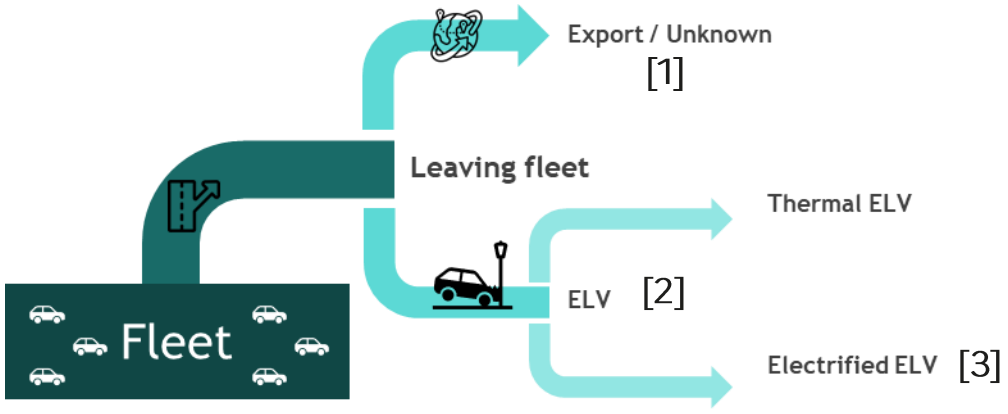


Figure 35: Diagram summarizing the various vehicle flows

PROJECTION OF THE LV FLEET

Based on projected new vehicle sales, the number of vehicles in circulation—the fleet projection—was calculated over a long-term horizon, taking into account both historical fleet data to calibrate the most recent market situation, and macroeconomic parameters such as population, GDP, car ownership rates, etc. (which vary according to the different scenarios and countries).

Based on the projected volume of the fleet, the combination of the composition of sales by powertrain from the WAPO model and a fleet exit law [1] (see Figure 35), the volume of vehicles by age and for the different types of powertrain can be calculated. The fleet output law is calibrated at this stage to a normal distribution, the central values of which are shown below for reference:

- *Green Constraint:* 14.6 years average age and 8 years standard deviation;
- *Green Growth*: 13.9 years / 8 years (faster switch to cleaner vehicles).

This is the average age of vehicles leaving the French fleet, and therefore includes those leaving for export (or unknown) and the flow of ELV.

Changes in the vehicle fleet and sales are monitored using the most recent historical volume data to refine the parameters of the output law. The assumptions used reflect this macro approach to renewal; differentiation is made by vehicle segment, but not by engine type (assumption of similar useful life, which is the carmakers' objective).

Note: further down, concerning the ELV flow **[2]** (see Figure 35), a differentiation will be made between vehicle types (see below for details of the resulting ELV flow).

SPECIFIC ASSUMPTIONS

During the first committee meeting to monitor this study (COSUI on February 18th, 2022), three questions emerged from the discussions between the participating members about possible impact factors to be considered in refining the flow modelling.

- *Unknown Whereabouts*

  Vehicles of unknown whereabouts are vehicles that have been withdrawn from circulation, but without a certificate of destruction issued or available to the authorities, and also without information available to indicate that the vehicle has been processed in an authorized processing center or has been exported.

  Previous studies have shown that the number of vehicles with an unknown location is around three to four million per year, compared with around six to seven million ELV treated in accordance with the ELV Directive and reported to Eurostat. However, the dedicated study[29] commissioned by the European Commission indicates that the majority of light vehicles with an "unknown whereabouts" should be considered as scrapped or hoarded within the EU-27, and that only a minority are exported in the form of second-hand vehicles or ELV used for spare parts.

  In this modelling method, we have therefore differentiated between the flow of vehicles leaving the French fleet **[1]**—evaluated on the basis of the exit law mentioned above—and the flow of ELV **[2]**, which will actually be processed by the industry, with the delta between the two corresponding to vehicles that are exported.

  Note: the model conducted here does not consider the impact of the AGEC law and the introduction of an EPR system for ELV with eco-organization(s) and/or individual system(s), which should lead carmakers to work on reducing the illegal system, in particular through communication campaigns targeting ELV holders.

- Battery life and expected vehicle age

  At present, most manufacturers already offer an 8- to 10-year warranty on the hybrid system, which includes the battery. Added to this is the prediction that an electric car battery will last between 10 and 15 years before needing to be replaced: from the point of view of technological mastery and the improvement of highly electrified architectures, we have clearly passed the stage of 'uncertainty' as to how long they will last.

  For the main flow of electrified ELV (excluding accidents), the anticipated end of life of the vehicle due to the mobility battery—not replaced because the cost is higher than the residual value—has been taken into account by means of an average age that is lower than for thermal ELV, but which will increase as their durability is expected to improve. A replacement market for mobility batteries should, however, gradually take shape in the event of the premature death of the battery, or in the more general case where extending the life of the vehicle is encouraged.

- Micro-hybridization vs. electrified vehicle architecture

  In practice, micro-hybrid vehicles (microHEV) are internal combustion vehicles that are only slightly modified, with no impact on the ELV treatment approach: this point

[29] Assessment of the implementation of Directive 2000/53/EU on end-of-life vehicles (the ELV Directive) with emphasis on the end-of-life vehicles of unknown whereabouts

will be detailed in phase 4 (see 6.1.1). They are therefore included in the thermal vehicles flow.

RESULTING FLOWS OF VHU [2]

As a summary of the previous design elements:

- The flows of thermal and electrified ELV have therefore been calibrated and differentiated by post-processing data on volume and average age, to ensure a better representation of reality:
  - On the one hand, there is a steady flow of thermal ELV, which will dry up over the long term;
  - On the other hand, there is a nascent flow of electrified ELV in long-term transition to its established regime.
- Compared with the corresponding fleet outflow **[1]**, the characteristics of the thermal ELV flow have been considered relatively stable over time, on the basis of what is currently known: the rate of retention of the outflow **[1]** as a function of age is therefore 75% of outgoing thermal vehicles aged 12 years or more (2021 reference rounded to 1,400,000 thermal ELV, i.e. approximately ¾ of outgoing thermal vehicles aged 12 years or more).
- In the case of electrified ELV, the withholding rate assumption chosen will evolve until the electrified fleet is established:
  - Until 2030, 75% of outgoing electrified vehicles aged 10 years or more, considering the lifespan of the batteries of vehicles sold before 2020;
  - After 2030, 75% of outgoing electrified vehicles aged 12 years and over, in line with the flow of thermal ELV.

As explained in the previous section on fleet projections, the number of vehicles in circulation each year, as well as their age and engine type, have been modelled and estimated. Thus, with the composition of the fleet by age, the fleet exit law and finally the scrappage law explained above, it is possible to calculate the volumes of ELV up to 2040 and by engine type. The granularity of the results retains the same level of detail in terms of segmentation and type of engine as that described above: the outflow of vehicles **[1]** and ELV **[2]** are differentiated by the seven segments of passenger cars and the four segments of light commercial vehicles, as well as by the different types of electrified MPG (BEV Low Range, High Range, and Very High Range), hybrid (MHEV, HEV, and PHEV), and fuel cells.

5.1.2. Refinement through combination with 2/3-wheelers and quadricycles

Discussions with ADEME's STM department ([30]) and ACEM ([31]) indicate that the electric market for these vehicle categories is currently poorly structured, in terms of supply, demand and regulation.

The data available did not allow any relevant figures to be considered to refine the view of 2/3-wheelers and quadricycles: these vehicles will therefore not be included in the scope of the study for phase 4.

5.2. Results and details of ELV flow projections for France

5.2.1. Planned global developments in electrification: a clarified framework

5.2.1.1. Change in the engine mix of the LV fleet

To better understand the results of the projections of electrified ELV flows, it is important to first have a clear overview of the composition of the fleet for all Light Vehicles by 2040, which is an essential intermediate step, as previously specified in the WAPO tool flowchart.

[30] ADEME Transport and Mobility Department ("Service Transports et Mobilités")
[31] Association of European Motorcycle Manufacturers (Association des Constructeurs Européens de Motocycles)

The underlying macroeconomic principles influencing the development of the fleet are as follows:

- Demographics;
- Gross Domestic Product (GDP) per capita;
- Motorization rate (MR): number of LV per 1,000 inhabitants.

For France, BIPE-BDO Advisory's long-term projections for 2021 are fairly stable overall in terms of population and GDP. For the highly urbanized countries of Western Europe, of which France is a part, considerations of changing mobility patterns combined with increasingly stringent requirements for the environmental performance of LV have led to the assumption that the MR is decreasing. Overall, the resulting assumption is that the French LV fleet is heading for an increasingly significant decrease:

Park (in Mu)	2021	2025	2030	2035	2040
[GC]	44.2	42.9	41.3	39.4	37.4
[GG]	44.2	42.9	41.2	39.3	37.3

Table 6: Change in LV fleet volumes in France
*- for the WAPO 2021 Green Constraint **[GC]** and Green Growth **[GG]** scenarios*

The change in the motorization mix of the LV fleet for the two green scenarios considered, illustrated below in Figure 36—i.e. the proportion in % of the fleet of each type of engine, as defined above in Table 5 (with gasoline, diesel, LPG and CNG versions, as well as three levels of range for Battery Electric Vehicles (BEV): "low", "high" and "very high")—shows that the trends are very similar overall up to 2040, mainly because the regulatory constraints implemented in the model severely limit the future technological offering (in particular the planned ban on ICE as of 2035): these constraints take precedence over the other parameters, which have become less influential on new sales, the slight differences being more related to the macro-economy specific to each of them. Added to this is the inertia effect of fleet renewal, the overall view of which attenuates the differentiation in new vehicle sales: over the period 2020-2040, for an average LV fleet of 41.1 Mu (million units), annual sales are of the order of 2.3 Mu.

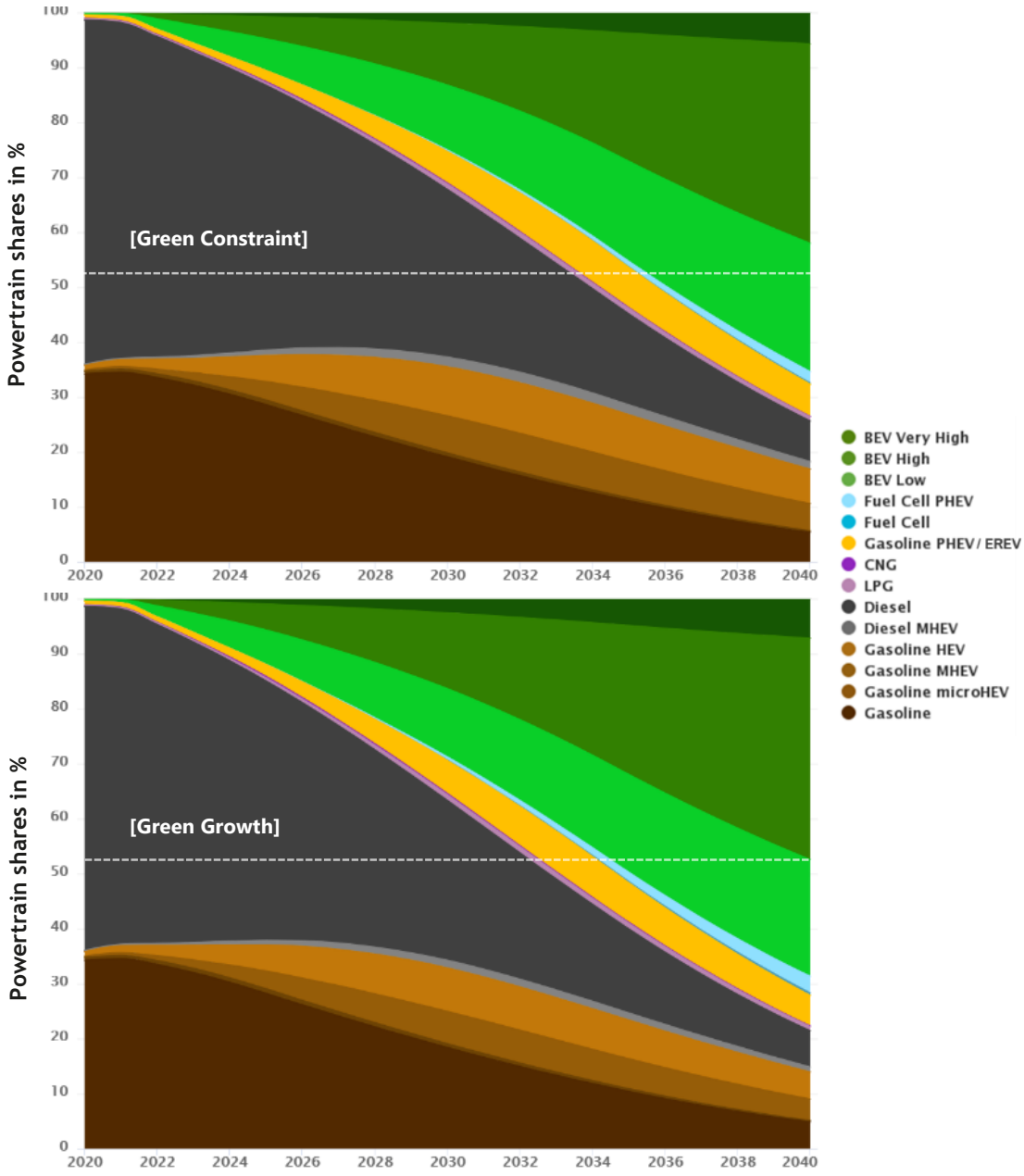


Figure 36: Change in the motorization mix of the passenger car fleet in % - for the WAPO 2021 Green Constraint and Green Growth scenarios

In detail, the composition of the 2021 fleet is essentially dominated by petrol and diesel combustion engines, while the proportion of electrified vehicles is less than 4%. The engine mix will diversify over the next decade, and different technologies can be found for the future electrified vehicles. In practice, the electrification of LV sales will accelerate after 2025, with the implementation of the EURO7 standard (around 2027), followed later by other European restrictions (in particular the "Fit for 55" described above: see 5.1.1.4), and will continue to increase. By 2035, electrified vehicles, particularly BEV, will make up the majority of the fleet:

- *Green Constraint:* 45.2% BEV and 25.4% fuel cells and hybrids;
- *Green Growth:* 49.7% BEV and 22.9% fuel cells and hybrids.

For ELV, volumes in absolute terms help gain a better understanding of trends and capture the elasticity of calculations of scenarios.

5.2.1.2. Flows of electrified ELV generated

In this section, the volume of ELV obtained in France for all five families of electrified vehicles represented in the WAPO is described in more detail.

The results for the two green scenarios are shown in the figure below. These volumes of ELV start to be significant in 2030 and increase notably from then onwards, with the current market essentially made up of traditional thermal petrol and diesel vehicles and less than 4% of electric and hybrid vehicles. As mentioned above, it is the forthcoming stricter European regulations—EURO7 expected in 2027 and Fit For 55 in 2030—that will accelerate the electrification of LV.

In these projections, the average age of thermal ELV is fairly stable at around 19.5 / 20 years until 2035. It then gradually increases—reaching 23 years in 2040—due to the gradual disappearance of sales of the same type and the resulting drying up of thermal flows from the fleet and ELV.

In the case of electrified ELV, the opposite effect is observed, with the gradual establishment of a substantial fleet (apart from any specific consideration of vehicles involved in accidents, since we are interested in the medium and long term when volumes become significant): in line with the assumptions on the RESULTING FLOWS OF VHU [2] described earlier, the average age is still low in 2025 at 11 years, due to the assumption of the lifespan of the batteries of older electrified vehicles; it is 14 years in 2030, then reaches 15 years in 2040.

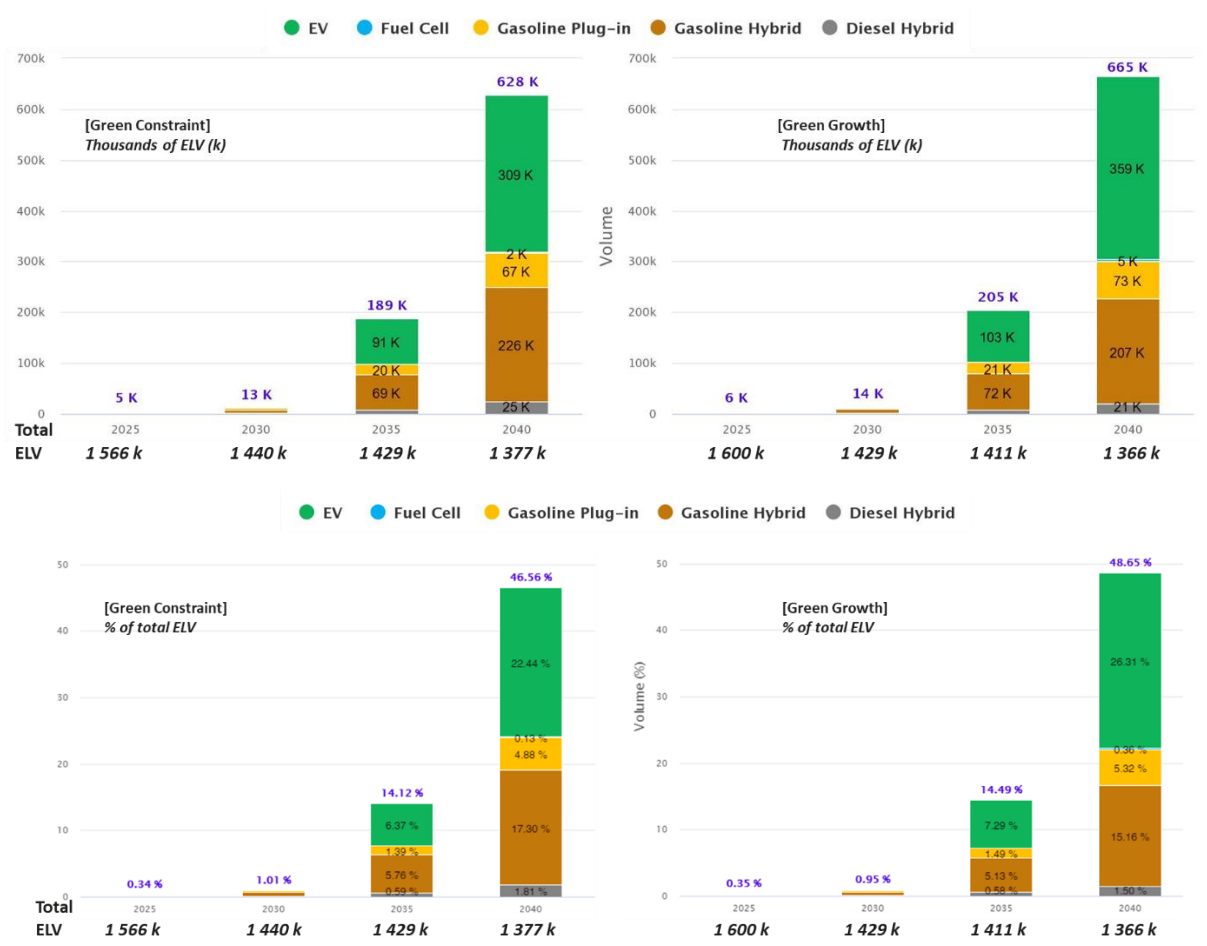


*Figure 37: Evolution of the volume of electrified ELV (in number and % vs Total) - Green Constraint **[GC]** and Green Growth **[GG]** scenarios*

As the trends in the flow of ELV are directly linked to changes in the number of vehicles registered, with a time lag, the major shift towards electrified ELV appears mainly after 2030, and the 'crossover' with the downward trend in the flow of combustion ELV occurs around

2040. Once again, the differences between the scenarios are linked to the different macroeconomic orientations, as well as to the fleet renewal dynamic, which is slightly faster in the case of the sustained energy transition *Green Growth* scenario.

With regard to hydrogen powertrains (fuel cells), around a hundred ELV are expected in 2035, followed by a larger volume of almost 5,000 units in 2040.

5.2.2. Detailed review of battery electric ELV: accelerated impact

This section focuses on the volume of BEV ELV. As explained in the previous section, the growth in registered electrified vehicles is extremely rapid, especially after 2030, and BEV make up the bulk of this. According to the projection tool used, the BEV fleet, established at less than 1% of the total in 2020, will reach around 25% in 2030 and just over 65% in 2040 for the *Green Constraint* scenario.

This change in the proportion of BEV in the total fleet is not just linked to the introduction of regulations: as BEV are still based on recent technologies that are not yet fully mature, even compared with hybrids, they are still expensive compared with other engines, and do not benefit from significant volume effects to reduce costs due to the limited range of products on offer. Technological developments and their wider availability in more segments will be the main reasons for both benefiting from volume effects on prices and making them more popular with users.

According to the results of the ELV projections for BEV (see figure below), the "Low Range" BEV will remain dominant overall. However, in the longer term—beyond the timeframe of this study—other levels of autonomy will also increase significantly, in particular the High Range, which will become the dominant type of BEV after 2030 (see fleet projection). For the *Green Growth* scenario, for example, the volume of High Range BEV ELV will be comparable to the Low Range volume in 2040, as a result of their increasing proportion in the long-term fleet due to a significant fall in prices and a better match between the range offered and the expected uses.

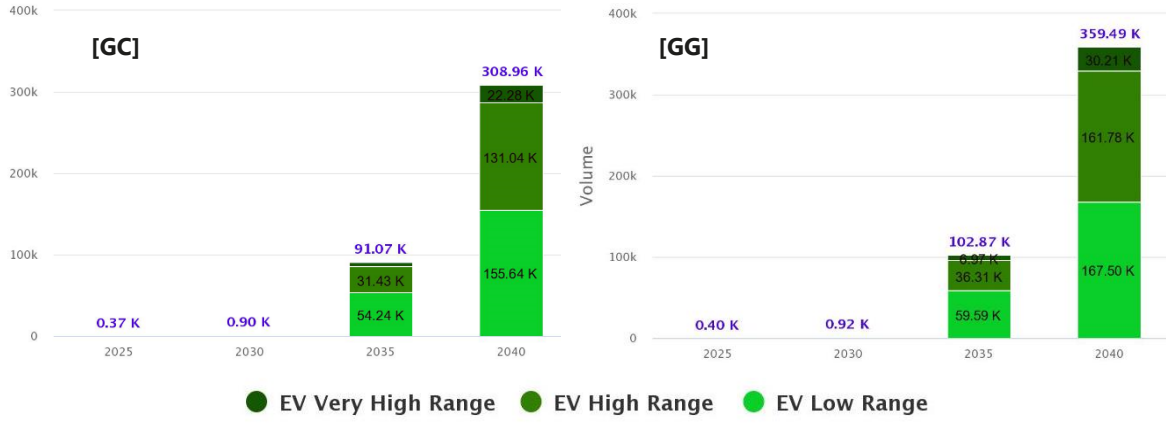


*Figure 38: Trends in the volume of different types of BEV ELV - Green Constraint **[GC]** and Green Growth **[GG]** scenarios*

5.2.3. Details of hybrid thermal ELV, a long transition

Hybrid vehicles based on combustion engines are the other main family in the flow of electrified ELV, with four main components.

Whatever the scenario, all hybrid powertrains will increase their share of the fleet in the medium to long term, with the exception of petrol micro-hybrids, which have a very limited range on the market and will disappear by EURO7 (expected in 2027). Overall, hybrid electric vehicles (HEVs) will account for the largest share of hybrid ELV volumes, and will gradually be joined by rechargeable hybrid vehicles (PHEVs), as these two architectures produce fewer

emissions than other hybrid powertrains (mainly due to their pure electric mode) and can therefore continue to be deployed in the longer term despite the stricter regulations to come.

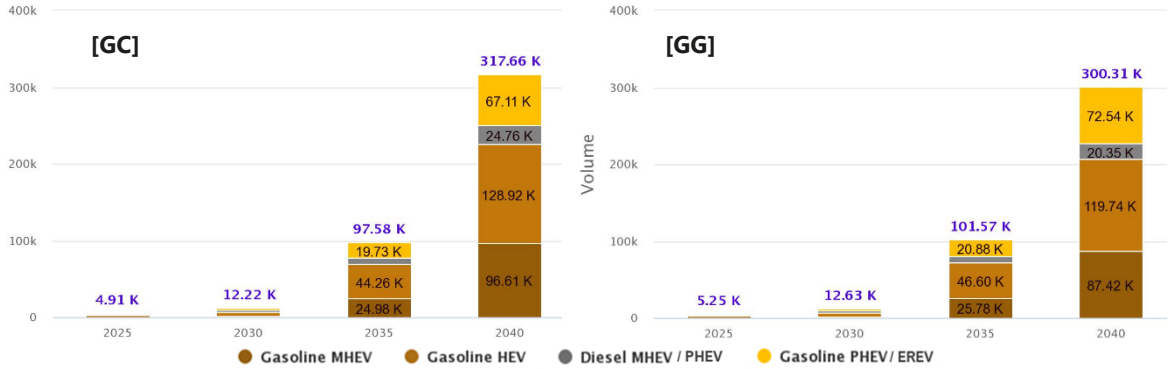


*Figure 39: Growth in the volume of hybrid thermal ELV - Green Constraint **[GC]** and Green Growth **[GG]** scenarios*

5.2.4. Key elements of the projections

The key figures are as follows:

- In the short term (2025-2030), electrified ELV will remain at low volumes, allowing the industry to prepare for the future;
- In terms of impact, 2030 appears to be the critical stage in terms of capacity, with around 15% of the total volume of electrified ELV;
- Added to this is the diversity of possible engines, another factor to be considered in the preparation and organization of ELV treatment centers;
- By 2040, the flow of thermal and electrified ELV will be close to the switch, with more than 45% electrified.

Phase 3 saw the implementation of the brick dedicated to the projections of ELV flows from the fleet, an essential and structuring milestone for the continuation of the study, which will in particular lay the foundations for the detailed volumes required for the various analysis plans in phase 4.

The specific assumptions will be detailed in the corresponding sections.

6. Phase 4 - In-depth analysis of the technical, organizational, and economic consequences of this change for the ELV sector

Changes to the car fleet are leading to:

- On the one hand, a fleet of thermal vehicles, the replacement of which will decline rapidly, but which will continue to generate a steady flow of thermal ELV for a long time to come;
- On the other hand, a small but fast-growing fleet of electrified vehicles, whose renewal rate will accelerate.

The aim of phase 4 is to present the technical, organizational and economic consequences for the ELV sector of changes in the vehicle and ELV fleets over different timeframes.

The aim of **the technical section** is to characterize electrified vehicles and highlight the differences between them and thermal vehicles in order to better understand the consequences for ELV, particularly in terms of:

- engine architectures;
- specific and useful parts and components, in particular to service the vehicle fleet;
- the material composition of vehicles.

The aim of **the organizational section** is to provide a reminder (see section 4.2) of the adaptations and new stages required for the treatment of an electrified ELV by ELV centers compared with the treatment of a thermal ELV, as well as the training and equipment required to carry out these new stages.

Finally, the aim of **the economic section** is to present the economic consequences of the transformation of ELV on the treatment sector, and more specifically:

- the evolution of the economic spin-offs and losses generated for the ELV treatment sector by the electrification of the vehicle fleet, distinguishing between the impacts of the various activities:
  - the dismantling of used ELV parts;
  - recovery of parts and materials from ELV;
- the investment required by ELV centers in terms of training and equipment for processing electric and hybrid ELV.

6.1. Technical aspects: characterization of electrified vehicles

This crucial stage lays the groundwork for understanding the distinctions between the different architectures of thermal, electric and hybrid vehicles. It is assumed that electric and hybrid vehicles will be more or less identical to thermal vehicles in all aspects other than those relating to the powertrain.

6.1.1. Differentiation of powertrain architectures

On the basis of their similarities or specificities, different families of vehicle powertrain architectures are analyzed in this section:

- Vehicles in the Thermal family, distinguishing between:
  - Pure combustion vehicles;
  - Micro-hybrid vehicles (microHEV).

  It is indeed important to understand that the micro-hybrid architecture (microHEV), even if equipped with a (small) electric motor, has no electric traction/propulsion capacity. In fact, the electric motor replaces some of the functions previously conducted indirectly by the ICE or other electromechanical

elements. The powertrain therefore remains completely unchanged. This microHEV architecture is therefore completely comparable to a conventional ICE.

- Vehicles in the Hybrid family, distinguishing between:
  - Light hybrid vehicles (MHEV);
  - Hybrid electric vehicles (HEV);
  - Plug-in hybrid vehicles (PHEV).

  This family therefore includes vehicles that are still powered by an ICE, but with a hybrid powertrain with electric drive. There are also variations in the positioning of the electric motor within the three categories and the high voltage already on board for the HEV and PHEV (the 48V standard having been adopted for the MHEV).

- Vehicles in the Electric family—also known as Zero Emission Vehicles (ZEV)—distinguishing between:
  - Battery electric vehicles (BEV);
  - Fuel cell vehicles;
  - Plug-in hybrid fuel cell vehicles (PFCV).

  Propulsion is then provided entirely by high-voltage electric motors.

The Electrified family therefore includes the Hybrid and Electric families.

The following table summarizes the similarities and specific features of vehicle architectures in relation to their engines. Based on a conventional thermal reference, the other types have been broken down into their main characteristic components. For information purposes, in connection with the organizational aspect, each component has been assigned to a category of elements: either standard because already dealt with by the industry, or new with an organizational impact to be specified.

Notes (see Table 7 below):

- The display of parts in merged cells conveys the idea that the part is the same for the different architectures (columns) concerned by the merged cell; unmerged cells with the same heading convey the idea that the part is of the same nature but may differ from one architecture to another (structure, position, performance).
- The components listed can be reused after dismantling (see following sections).
- In practice, hybrids—MHEV, HEV and PHEV—have small or medium capacity batteries (in kWh), with all the cells subject to very demanding charge/discharge cycles, to provide short but very regular peaks of power.

ICE family		Electrified Family						
		Hybrid family			*Electric family*			
ICE	**microHEV**	**MHEV**	**HEV**	**PHEV**	**BEV**	**PFCV**	**Fuel Cell**	***Category***
Internal Combustion Engine								***Mechanical components***
ICE accessories: valve actuation, exhaust pipe…								***Mechanical components***
Catalytic converter								***Mechanical components***
Transmission	Transmission	Transmission - hybrid	Transmission - hybrid	Transmission - hybrid	Transmission - electric	Transmission - electric	Transmission - electric	***Rotating Machine***
Control	Control	Control	Control	Control	Control	Control	Control	***Electronics***
Battery 12V	Battery 12V							***Battery - Accessories***
	Elec. motor (no drive)	Electric drive	Electric drive	Electric drive	Electric drive	Electric drive	Electric drive	***Electric Machine***
		Power Battery	Power Battery	Power Battery	Energy Battery	Energy Battery	Energy Battery	***NEW: Mobility Battery***
		DC/DC converter	DC/DC converter	DC/DC converter	DC/DC converter	DC/DC converter	DC/DC converter	***Mechatronics***
	AC/DC inverter	AC/DC inverter	AC/DC inverter	AC/DC inverter	AC/DC inverter	AC/DC inverter	AC/DC inverter	***Mechatronics***
				Onboard charger	Onboard charger	Onboard charger		***Mechatronics***
				Charging port	Charging port	Charging port		***Connector technology / Wiring harness***
Standard	Standard	Standard	High Voltage Cables	High Voltage Cables	High Voltage Cables	High Voltage Cables	High Voltage Cables	***Connector technology / Wiring harness***
Thermal Management	Thermal Management	Thermal Management	Thermal Management	Thermal Management	Thermal Management	Thermal Management	Thermal Management	***Thermal-fluidic System***
						Fuel Cell stack	Fuel Cell stack	***NEW: Fuel Cell***
						FC system & integration	FC system & integration	***Thermal-fluidic System***
						H2 tank	H2 tank	***NEW: Composites & High Pressure***

standard ICE | specific electrification | specific Fuel Cell

Table 7: Differentiation of architectures at the level of the main powertrain components

6.1.2. A closer look at the material composition of vehicles

The following figure shows the difference in material composition between a standard thermal vehicle (VW Golf) and an equivalent BEV (Chevy Bolt), in the C-Low vehicle segment. Overall, the figure confirms the emergence or increase in the use of certain materials required for components specific to the electrification of the vehicle, such as power electronics and, of course, the mobility battery and electric motor.

It should be noted that the disappearance of the catalytic converter on BEV and fuel cells vehicles (see table above) will result in a significant loss of revenue from the processing of ELV: this point will be addressed specifically in the economic section (see "Economic section" 6.3.1.2).

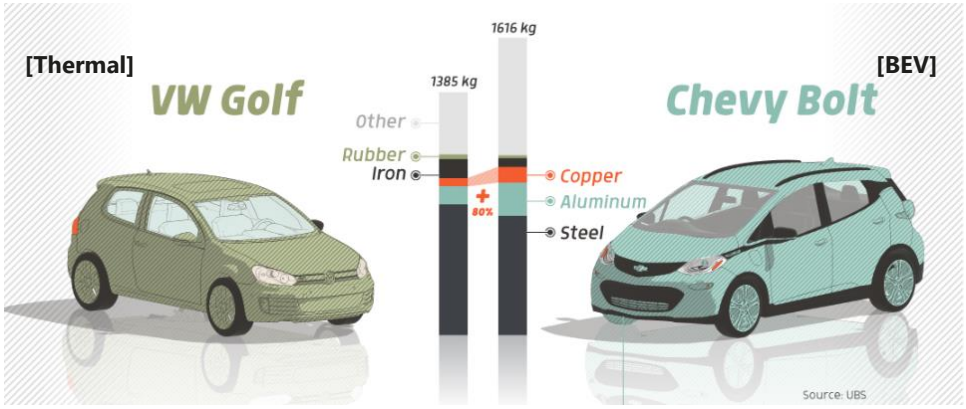


Figure 40: Comparative illustration of the material composition of thermal vehicles and BEV - 2018[32]

Apart from the extra weight, which is mainly due to the batteries, this illustrates, from a design and manufacturing point of view, the greater use of more noble materials because of the new functions to be performed and the performance expected of the BEV—thus leading to components with higher added value—in particular:

- copper, which is used extensively in batteries and electric motors;
- aluminium, to make vehicles lighter, or possibly for the housing of mechatronic parts (technology combining mechanics, electronics and IT).

MATERIAL	(As a % of vehicle mass)		Evolution
	VW Golf (thermal)	Chevrolet Bolt (BEV)	BEV vs thermal vehicle
Ferrous metals	61.7%	43.4%	*- 14%*
Aluminium	7.3%	11.1%	*+ 85%*
Copper	3.5%	5.2%	*+ 80%*
Rubber	1.9%	1.1%	*- 29%*
Other	25.5%	39.3%	Up sharply, thanks in particular to the mobility battery

Table 8: Comparison of the material composition of thermal and electric vehicles (illustration with two vehicles, a thermal VW Golf and an electric Chevrolet Bolt)

With regards to the main components linked to the powertrain, as identified according to the architecture identified in Table 7, research has been carried out into their design—sizing in relation to engine power, technical data sheets, material composition and reference weights, etc.—to assess their average composition, focusing on materials that can potentially be recycled:

- Ferrous metals, aluminium, copper;
- Rubber, plastics;
- Electronics, rare earths.

For example, for a BEV in segment C with a 100 kW engine, the material sheet obtained for all the elements specific to electrification—see Table 7, excluding the mobility battery—is as follows:

BEV segment C - powertrain 100 kW (excluding batteries)		
MATERIAL	Weight (kg)	*Margin*
Aluminium	37.0	*+/- 10 %*
Steel	31.0	
Copper	22.8	
Ferrous metals	4.8	
Rubber	3.2	

[32] https://www.visualcapitalist.com/how-much-copper-is-in-an-electric-vehicle/

Electronics	3.0	
Rare earths	1.2	
Plastics	1.0	

Table 9: Example of a material sheet for elements specific to the electrification of the powertrain

To further illustrate the transformation of architectures, it is interesting to compare, in terms of overall content and price of on-board functions, the two extremes represented by a vehicle with pure thermal powertrain and a BEV:

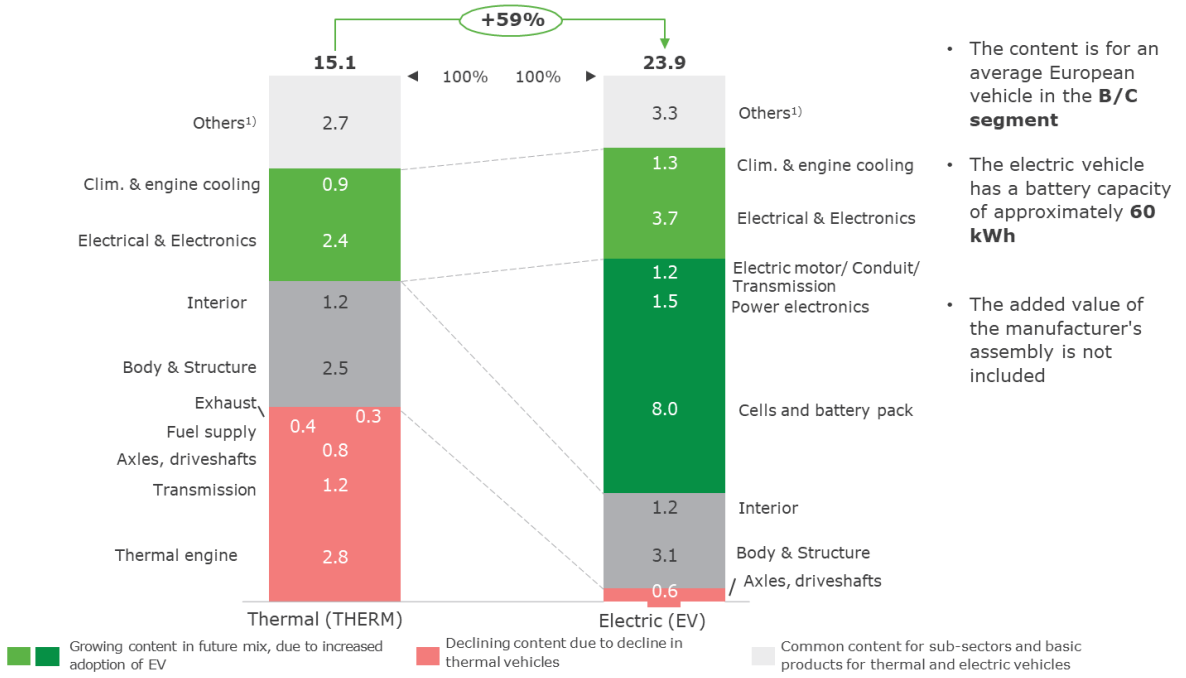


Figure 41: Average vehicle content by domain in thousands of euros / vehicle - 2019[33]

Excluding the powertrain, the vehicle remains fundamentally the same: it is in the logic and interest of manufacturers to maintain a high level of standardization. In detail, there has also been a significant increase in some other contents, such as the thermal management system and even on-board electronics.

As far as the Electric Family is concerned, because of efforts to reduce weight (for greater driving range) combined with the structural function increasingly given to mobility battery packs, a lower mass of economically recoverable materials is expected. However, this will mainly be achieved through the use of more noble materials (aluminium vs steel, for example). Overall, this means that the value of the body and structure assembly—also known as the body in white—is likely to be of the same order, or even slightly higher, as described in the study from which the figure above was taken (multi-sector study "Fit For 55" AlixPartners for the PFA, 2022). Similarly, Figure 41 illustrates the increase in the price of the content of the vehicle sub-perimeter from 2,500 to 3,100 euros, which includes the bodywork and structure.

6.2.Organizational aspects: approach to processing an electrified ELV

This section applies the ELV treatment approach in practice, but also from a modelling point of view. This should provide a better understanding of the potential impact of the distinctions

[33] Fit For 55" multi-sector study by AlixPartners for the PFA, 2022: https://pfa-auto.fr/wp-content/uploads/2021/12/Etude-Multisectorielle-PFA-AlixPartners-1.pdf

to be made between the various thermal and electrified vehicles, and then their use in assessing the economic benefits—or losses—(see economic section, 0).

6.2.1. Successive stages in dismantling ELV

The arrival of electrified ELV does not call into question the general operational approach of ELV centers:

- from the point of view of supervision of the activity, the regulations in place apply to all LV;
- from an economic point of view, it is always in the industry's interest to have the best possible recovery from the ELV it treats, and therefore to encourage the sale of the vehicle's contents in the most commercially attractive form (depending on the type of ELV center in question).

RESALE OF USED PARTS

In the context of the industry's economic activity, the resale of parts after dismantling for their functionality is strongly favored precisely when the price of the function they fulfil is high compared with the costs required to enable their resale.

Three scenarios are considered here:

- Reuse: any operation whereby products or components that are not waste are reused in the automotive sector for the same purpose for which they were designed;
- Remanufacturing: remanufacturing is a rigorous and standardized industrial process[34] which enables a used part or product to be returned to a state of performance and functionality equivalent to or even superior to that of the original, for the same use. This process enables parts/products to be refurbished to a uniform level of quality and performance from 1st to the last[35];
- Repurposing: any operation that has the effect of using components or sub-components for purposes or applications other than those for which they were initially designed, in a sector other than the automotive sector.

At this stage, there is no official definition of these specific concepts for the ELV sector in France. However, definitions are given in two documents (see glossary):

- For reuse, remanufacturing and repurposing in the following areas:
  - Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on batteries and waste batteries and repealing the directive amending Regulation (EU) 2019/1020;
  - BONJEAN Anne-Charlotte (ADEME), WHITWHAM Marguerite (Philgea), TREBESSES Gabrielle (Moringa), ZWOLINSKI Peggy (INP Grenoble), ROCCHI Valérie (INP Grenoble) 2023. Study on remanufacturing. 55 pages;
- For reuse and preparation for reuse in Directive 2008/98/EC.

MATERIAL RECOVERY

When resale as used parts is not possible, the complementary approach concerns any operation aimed at economically recovering the materials of components from ELV that are not intended for reuse, remanufacturing or repurposing. This covers two cases:

- End-of-life parts, for which the material content is well known and has a proven value in terms of more or less direct recycling and with an identified dedicated channel, which will be dismantled to be resold for material recovery;
- The residual carcass, with all the parts that have not been dismantled (intervention costs higher than the possible benefits), for shredding, post-shredding sorting, and material or energy recovery.

6.2.2. Implications for the ELV management and treatment process

TREATMENT STAGES

By examining the details of the vehicle architecture in terms of the main powertrain components (see Table 7), it is important to identify the steps required by ELV centers to process electrified ELV, either because they are new:

[34] Where standardized means "which eliminates variations in the operational process in order to achieve uniform components/products in terms of quality and performance".
[35] Source: BONJEAN Anne-Charlotte (ADEME), WHITWHAM Marguerite (Philgea), TREBESSES Gabrielle (Moringa), ZWOLINSKI Peggy (INP Grenoble), ROCCHI Valérie (INP Grenoble) 2023. Study on remanufacturing. 55 pages.

- Specific de-energization of high-voltage vehicles (HEV, PHEV, BEV, PFCV and Fuel Cell);
- Removal of the mobility battery (for the whole Electrified family);

or whose scope is simply extended compared to the current treatment of conventional thermal ELV:

- Dismantling and extraction of specific electrification components (all those identified in green in Table 7): because of their functionality and higher-value material content, it is assumed that it is economically worthwhile to systematically dismantle them for resale as parts or for material recovery before shredding the ELV carcasses;
- Dedicated dismantling of the heat pump and H_2 tank systems (for fuel cell architectures).

The essential initial stage—de-energizing the ELV and removing the mobility battery—requires specific operating conditions, particularly in the case of High Voltage (HEV, PHEV, BEV, PFCV and Fuel Cell), see section 4.2.

To enable ELV centers to process electrified ELV, this requires in particular:

- staff training for:
  - removing batteries (training for B2XL live working authorization and training for B2TL live working authorization, plus advanced training for work on damaged batteries);
  - performing battery diagnostics;

- a corresponding need for equipment for:
  - battery removal (cranes and lifting tables, not necessarily specific to this stage);
  - performing battery diagnostics (diagnostic interface).

In addition, insulated tools for working with electrical equipment and PPE will be required. However, ELV centers are often already equipped with these tools and PPE, which they use for tasks other than processing electrified ELV and batteries.

RISK MANAGEMENT

The arrival of electrified ELV also implies a change in risk management. Indeed, damaged electric batteries can present an increased risk of fire and electrocution. As indicated in section 4.1.2.2.7 several solutions have been put forward by the most advanced ELV centers and by carmakers. These solutions may vary between ELV centers depending on their specific characteristics (e.g. available space, urban or rural area, etc.):

- implementation of a "quarantine" procedure for at-risk electrified ELV, where they are stored in a dedicated area before being processed (installation of signage and reorganization of areas);
- storage of the battery or the electrified ELV on a "water tank" where, in the event of a fire, the ELV or the battery is submerged;
- storage in a fireproof container;
- storage of electrified ELV or batteries in dedicated warehouses.

Note: at the time of writing this report, MOBILIANS was working with the French National Institute for the Industrial Environment and Risks (Ineris) on a study into the management of batteries from end-of-life electric and hybrid vehicles by approved ELV centers, focusing in particular on regulations, risks and best practices.

6.3. Economic aspects: changes and quantified impact on commercial activity

The economic section aims to present:

- On the one hand, the evolution of the economic spin-offs and losses generated for the ELV treatment sector by the electrification of the vehicle fleet, distinguishing between the impacts of the various activities:
  - Second-hand parts dismantled from ELV for reuse and remanufacturing ;
  - Residual parts dismantled from ELV for:
    - Repurposing: use in another function;
    - material recovery;
  - Recovery of the remaining ELV after dismantling all the parts.
- On the other hand, the investment needed by ELV centers in terms of training and equipment for processing electric and hybrid ELV.

In this section, we will take a different approach to the economic activities generated by thermal ELV and electrified ELV, in order to fully understand the specific mechanisms at work depending on the type of vehicle to be treated.

6.3.1. Sale of used parts and material recovery

This section uses modelling to assess and quantify the economic benefits—or losses—generated for the industry by the electrification of the vehicle fleet, distinguishing between the various activities of ELV centers.

6.3.1.1. Used parts dismantled for reuse, remanufacturing, and repurposing

6.3.1.1.1. Choice of implementation in modelling

For the resale of dismantled second-hand parts, the chosen approach considers the resale of specific components of the electrified powertrain as second-hand parts in a global manner, without necessarily distinguishing between the three scenarios—reuse, remanufacturing, repurposing—specified above in section 06.3.1.2 (except in the specific cases of batteries and fuel cell elements):

- Firstly, because of their intrinsic value—the technologies applied, the materials used, the importance of the function—it can be assumed that the price difference between the three options remains relatively small;
- Secondly, because of their complexity: for the components under consideration, only limited intervention to restore (remanufacturing) or adapt their functionality (repurposing) can be justified, otherwise, they would be considered too damaged and/or too expensive to be re-exploited.

It is important to take this methodological element into account when developing the various sub-sections of this economic section. Based on the modelling of the electrification of the fleet and the flow of ELV (phase 3), the additional projection steps are summarized below.

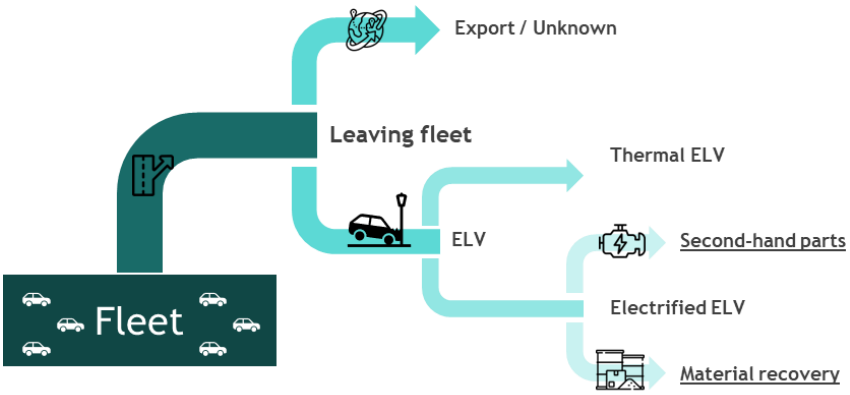


Figure 42: Overall flow chart for the flow decomposition methodology

For electrified ELV, it is important to remember that only the specific aspects relating to the powertrain will be studied in depth here to understand its impact; the other areas of the vehicle—passenger compartment, interior equipment, running gear—are evolving in a very similar way across all vehicle types.

The flow of thermal ELV corresponds to that which is already managed in terms of treatment; the study will then focus on assessing the effects of reducing this proportion of thermal ELV, in the context of changes in the economic activity of the sector.

6.3.1.1.2. Comparative dynamics of ELV fleets and flows

To begin with, it is essential to look at the different trends in the thermal and electrified vehicle fleets, which will experience opposite dynamics that will have a direct impact on the demand for used parts, and therefore the corresponding commercial activity. The larger a vehicle fleet is in relation to the flow of ELV of the same type—hence in terms of ratio—the greater the need for specific used parts.

The table below shows the projections for the various time horizons:

- The number of vehicles in the fleet (see 5.2.1.1);
- The number of ELV (see 5.2.1.2);
- ELV/vehicle fleet ratios, which provide information on the potential for reusing parts in their respective fleets, and therefore on the resulting demand. For example, in 2030, one thermal ELV could serve 14.9 vehicles in the French vehicle fleet.

	2021	2025	2030	2035	2040
Thermal Park	42,733,940	33,670,456	21,299,162	11,583,371	5,212,165
Thermal ELV	*1,400,000*	1,560,433	1,426,978	1,240,049	748,406
Thermal Ratio	*30.5*	21.6	14.9	9.3	7.0
Electrified Park	*1,507,233*	9,265,327	20,033,446	27,826,450	32,189,248
Electrified ELV	*1,000*	5,282	13,124	188,684	628,378
Electrified ratio	*1,507*	1,754	1,527	148	51.2

Table 10: Volumes of circulating fleets and flows of ELV per year (in number of vehicles) and associated Thermal and Electrified ratios, Green Constraint scenario

A low ratio means that the average demand associated with each ELV is low. On the contrary, a high ratio means that the average demand associated with each ELV is high: this is clearly the case for electrified ELV until at least 2035. This is an interesting parameter to consider in the modelling and projections to follow, but it is not the only one, as the export of reusable parts, for example, is another factor influencing economic activity.

6.3.1.1.3. Impact on commercial activity

In this section, three topics will be covered in the following order:

- developments in the resale of used parts from thermal ELV, using a macroscopic approach;
- the assessment of the resale of used parts from electrified ELV, based on detailed modelling;
- the overall impact on commercial activity.

IMPACTS ON THE RESALE OF USED PARTS FOR THERMAL ELV

To characterize the turnover generated by the sale of used parts for reuse from thermal ELV, two main dimensions are considered:

- the proportion dedicated to serving the French vehicle fleet;
- exports, which generally refer to the flow of vehicles exported from the French fleet (or other markets of a similar type), i.e. in general towards outside Western Europe.

The first dimension is therefore directly derived from the demand for the associated vehicle fleet in France, itself linked to the combined consideration of the thermal ratio (explained earlier in section 6.3.1.1.2) and the volume of thermal ELV available; however, it is also important to take into account future trends in the overall spare parts market (including new and reused parts).

The annual flow of thermal ELV will most likely fall by 2040 (to 748,000 units) and will be almost halved compared with 2021 (1.4 million units): the result will be a smaller volume of reusable parts available. In addition, the thermal ratio will also fall significantly in the long term, as the thermal fleet dries up: in practice, there will be fewer potential customer vehicles. The resulting effect is a theoretical reduction in activity in France. On the other hand, it is assumed that the macro-economic context is tending towards a reduction in average spending on cars. Combined with the organization of the ELV processing sector to improve the corresponding offer (expanded offer of reuse parts, more efficient market access via digital tools, etc.), this should result in a logical increase in the circular economy, illustrated by a growing share of reuse in the spare parts market. Overall, therefore, a clearly positive effect is expected on the economic activity in question.

For the second dimension, in the export scope—thus serving an established fleet that is maintained or may even increase—, based on similar assumptions, the demand for reusable parts will be considered to be at least maintained.

The annual activity figures for the industry[36]—approximately 500 million euros for the used parts market in 2021—in relation to the Thermal segment alone (see Table 10) gives us an idea of the average level of economic activity generated by the sale of parts for reuse by ELV. On this basis, by applying a growth rate to this average level until it stabilizes in 2030 (assumption of +50% vs. 2021), the following projection is obtained:

[36] https://www.largus.fr/pros/actualite-automobile/les-propositions-de-mobilians-pour-perenniser-le-vhu-10949390.html

	2021	2025	2030	2035	2040
Thermal Park	42,733,940	33,670,456	21,299,162	11,583,371	5,212,165
Thermal ELV	1,400,000	1,560,433	1,426,978	1,240,049	748,406
Thermal Ratio	*30.5*	*21.6*	*14.9*	*9.3*	*7.0*
Average sales EUR/thermal ELV (vs 2021)	357	429 (+ 15 %)	557 (+ 50 %)	557	557
Used parts sales (millions of euros)	*500*	641	762	662	400

Table 11: Estimated sales growth in the thermal second-hand parts market

The assumption that average sales per ELV will stabilize as of 2030 suggests that the loss of business from the French fleet—with a falling thermal ratio and low value—will be offset by increased export activity, with in practice a lower total volume of parts to be sold (only 748,000 thermal ELV in 2040, compared with 1,427,000 in 2030).

Note: if we consider all the thermal ELV currently being processed (1,400,000), the average turnover generated from second-hand parts is EUR 357 per ELV; if we consider ELV whose parts are currently being dismantled for the second-hand market (865,082 ELV in 2020[37]), the average turnover generated from second-hand parts is EUR 578 per ELV. The approach presented above considers the flow of ELV as a whole, with the growth in average revenue per ELV coming from both a greater number of parts dismantled for resale and a greater number of ELV reprocessed for this purpose, without differentiating in more detail.

IMPACTS ON THE RESALE OF USED PARTS FOR ELECTRIFIED ELV

1. Quantifying the amount of parts that can be used for second-hand sales

This section will explain the methodology used to calculate the numbers and types of used parts that will result from the projected flow of electrified ELV. This "conversion" of the flow into parts involves first the estimation of the proportion of the volume of electrified ELV that can be dismantled for resale of second-hand parts, and then assessing, for each specific powertrain component, the portion that will actually be able to meet the resale requirements (functional interest, residual useful life, performance).

The first aspect to be considered is the estimated dynamic of demand linked to the needs of the French vehicle fleet: in the case of electrified vehicles, it is considered that exports do not have a significant influence on the parts sales business, due to the relative technical complexity of customer vehicles. Using the ratios set out in Table 10 above, it would appear that the Electrified ratio (for the Electrified family as defined previously) is advantageous for the demand side due to the scarcity of available electrified ELV, all the more so considering that, for the reasons mentioned above in the case of thermal ELV, the circular economy will strongly develop:

- in reuse and remanufacturing, of course;
- for certain elements, also in repurposing because of the advantages of the dismantled part (functionality, content).

[37] ADEME (2022). Vehicles - 2020 data - Annual report

In this context, and considering that the market is in a rapid structuring phase, the assumptions made about the potential for conversion of electrified ELV into dismantled parts—known as *Elec_Rate*—are as follows:

- 100% in 2025 and 2030;
- 70% by 2035;
- 50% by 2040.

The portion of the electrified ELV stream that is not "converted" will therefore be recovered in terms of materials, as described below.

Note: It is important to understand this theoretical representation: here, it indicates the percentage of electrified ELV in a given year leading to maximum recovery of parts—hence dismantled and available for resale—to meet overall demand and thus maximize the corresponding economic activity (for the powertrain perimeter under consideration); in reality, the way the industry operates and the capacity of each dismantling center to resell its used parts means that a greater number of ELV are partially dismantled, for a smaller number of parts recovered per ELV. Overall, the aim here is to target an equivalent volume of dismantled parts between the two approaches. To illustrate, from a modelling point of view, this means that up until 2030, all the components specific to the powertrain of electrified ELV should be dismantled to meet the need for second-hand parts; from 2035 onwards, a smaller proportion would be dismantled (70% in this case, since the Electrified ratio is close to 148); in 2040, 50% of the flow of ELV would be used to meet demand (Electrified ratio goes sharply down to 51.2 but the circular economy should be well established in people's habits by this time).

In addition to the ratios detailed above, it is important to consider the durability of specific electrification components in relation to their use. For the mobility battery and for Fuel Cells, it is assumed that the useful life of vehicles should rapidly approach 15 years. For the other main components, the lifetimes are higher because the uses are well controlled and the components are therefore subject to less wear and tear. The table below shows the useful life of the various components, with equivalent use:

Component	Durability
Transmission	30 years
Electric drive	40 years
Battery pack	15 years
DC/DC converter	20 years
AC/DC inverter	20 years
Onboard charger	20 years
Charging port	30 years
High Voltage Cables	20 years
Thermal system	20 years
Fuel Cell stack	15 years
Fuel Cell integration	20 years
H2 tank	15 years

Table 12: Assumptions for average useful lifetimes of the electrification components (BDO Advisory)

Based on these estimates, logically, the longer a part lasts, the greater the possibility of reselling it as a (quasi) functional part after dismantling—mainly for reuse and remanufacturing, but also for repurposing—: for these parts with high added value, it is more economically attractive to find a second-hand market than to resell it for material recovery. The resulting assumption for converting components into used parts for resale—known as the *Durability_Rate*—is therefore taken as follows:

- only 10% of the parts that have a durability of 15 years are selected, since the age of the ELV is approaching the end of life of the component; for mobility batteries,

this is an assumption of reuse only (remanufacturing and repurposing considered elsewhere);
- 30% of the parts that have a durability of 20 years are selected;
- Lastly, 90% of the parts that have a durability of 30 years or more are selected, as their lifespan clearly exceeds that of the ELV from which they are derived.

Note: logically, the longer the part lasts in relation to the age of the vehicle, the less demand there should be for them in the corresponding fleet; in this case, repurposing should be considered the most appropriate economic model.

The flow of used parts from electrified ELV that can be resold is therefore calculated as follows:

Flow of used parts = Flow of electrified ELV x *Elec_Rate* x *Durability_Rate*

2. Economic impact

A. Powertrain used parts

For the economic value based on projections for used parts from electrified ELV, it has been assumed that the price of used parts is indexed to the cost of new parts. In practice, this gives:

- a resale price for parts that are still functional—reuse or even very light remanufacturing— equivalent to 50% of the price of new parts;
- there is an exception for a few items with a higher intrinsic value to take into account a more sustained demand, as is the case for:
  - the mobility battery at 60% of the new price, since only reuse is considered here;
  - the hydrogen tank at 75% of the new price.

This approach is based on the projected new vehicle costs excluding margins already implemented in the WAPO 2021 model: this allows us to capitalize on reference data validated by the members of the PFA.

Given that the model's original input assumptions apply to sub-assemblies, an additional price decomposition step was necessary, again using the recently established[38] BEV reference (see figure below).

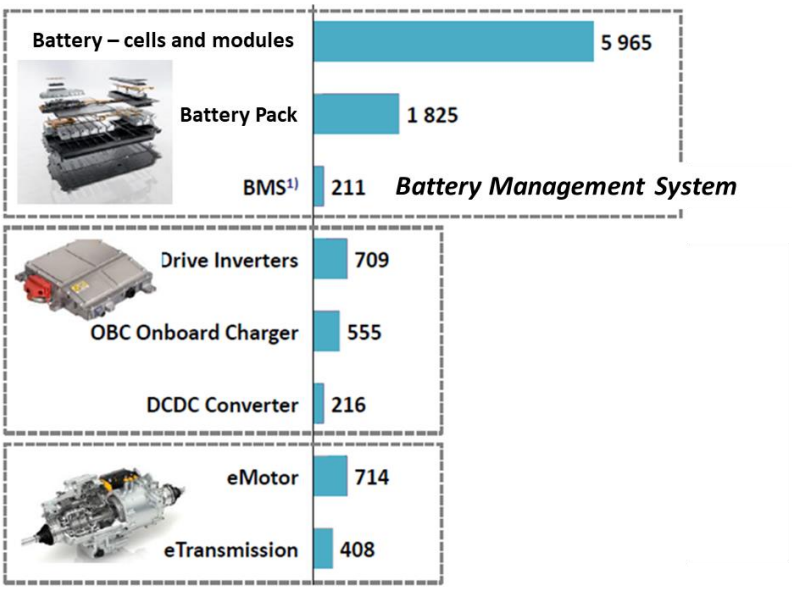


Figure 43: Price breakdown of a BEV powertrain in EUR - 2019

[38] Fit For 55" multi-sector study by AlixPartners for the PFA, 2022

As a reminder, the sizing of specific electrification components depends on the vehicle segment, the type of architecture, and the power associated with the powertrain. This segment-architecture-power granularity is directly considered in the calculations via the WAPO model but in practice can only be returned in an aggregated way.

The following table summarizes the results of the modelling method described above, which shows both the projected volumes of used parts as defined above with Table 12 (or kWh for mobility batteries), as well as the economic weight associated with specific electrification components.

To illustrate the calculation chain described above for ELV conversion rates:

- For mechatronics in 2030: 100% of the 13,124 electrified ELV were considered, including 30% of parts retained for DC/DC converters, inverters and on-board chargers, i.e. a total of 9,110 parts available for resale;
- For batteries in 2035: 70% of the 188,684 electrified ELV were considered, including 10% of the packs selected, i.e. 301,327 kWh still functional for direct reuse in electrified light vehicles.

As soon as a significant flow of electrified ELV is established, the commercial activity of selling parts for reuse is significant.

	Electric Drives	Transmissions	Mechatronics	Thermal Management	Fuel Cell Systems	H2 Tank	[kWh] Battery Pack	TOTAL - EUR
2025								
Volumes	2,586	2,586	3,670	111			2,804	
Value - EUR	1,279,388	731,079	1,051,072	9,211			276,163	**3,346,913**
2030								
Volumes	6,410	6,410	9,110	270	2	0	6,931	
Value - EUR	2,948,802	1,685,030	2,420,557	21,143	2,190	979	451,660	**7,530,361**
2035								
Volumes	86,337	86,337	102,603	19,131	10	3	301,327	
Value - EUR	27,515,028	15,722,873	20,470,322	1,541,527	7,259	4,305	14,508,761	**79,770,074**
2040								
Volumes	207,686	207,686	245,201	46,608	351	88	807,945	
Value - EUR	62,143,632	35,510,647	45,550,008	3,694,224	204,270	139,379	35,677,227	**182,919,388**
Total Volumes	**303,019**	**303,019**	**360,584**	**66,121**	**363**	**91**	**1,119,007**	

Table 13: Estimated growth in sales of used parts excluding powertrain for electrified ELV, Green Constraint scenario

B. Non-powertrain used parts

For the electrified fleet, a volume of revenue generated by the sale of used parts that are not specific to electrification also still exists, such as thermal management and air conditioning components, bodywork components, etc. All the different products in the non-powertrain scope represent a market share in value terms of around 57% on the spare parts sales market[39]. This 57% share will be considered constant over time for the non-powertrain economic activity associated with electrified ELV.

To estimate the turnover generated by the sale of used parts from electrified ELV, excluding powertrain, the projections are based on the Thermal benchmark used previously for average turnover per ELV overall (EUR 357, of which 57%, or EUR 206, is for the non-powertrain scope). The significant difference between the Thermal and Electrified ratios is of course important; demand for parts for electrified vehicles on the road will be much higher, as few electrified ELV will be available to service it: this increase in demand must therefore be considered.
Again based on the 2021 reference, the first assumption would be to use the ratio of these ratios to establish an average turnover excluding powertrain per electrified ELV. However, in the transitional period during which the electrified fleet and the flow of electrified ELV are being established—i.e. up to and including 2030—this approach is not realistic, requiring a more conservative secondary assumption to contain the inertia effect of establishing the flow of electrified ELV: at most, the average turnover generated by an electrified ELV will be ten times that of a thermal ELV. Under these conditions and based on the volumes of electrified ELV available at each time horizon, the following estimate has been established:

	2025	2030	2035	2040
Electrified ELV (*number per year)*	5,282	13,124	188,684	628,378
Application bonus (= Electrified Ratio / Thermal Ratio 2021) **Conservative limitation assumption*	*(~~57.5~~)* 10*	*(~~50.0~~)* 10*	4.8	1.7
Sales of used parts excluding powertrain (millions of euros)	12.5	40.4	280.4	324.3

Table 14: Estimated growth in sales of used parts excluding powertrain for electrified ELV, Green Constraint scenario

In practice, there will be a very sustained demand for spare parts, as usual linked to the use of vehicles, whether electrified or not: windscreen wipers, shock absorbers, headlamps, etc. This contribution to the processing activity, as illustrated in the table above, is fairly quickly non-negligible, once again because of the low flow of electrified ELV compared with the fast growing vehicle fleet.

IMPACT ON COMMERCIAL ACTIVITY

[39] FIEV-EQUIP AUTO Paris study, 2022

The following table gives a global overview of the ELV used parts sector as a whole, aggregating projections for Thermal economic activity and growth linked to the electrified fleet:

	2025	2030	2035	2040
Total used parts turnover Used thermal and electrified vehicles (millions of euros)	656.7	809.8	1,022.2	906.8
Average turnover EUR / ELV (vs 2021)	419 (+ 17 %)	562 (+ 57 %)	715 (+ 100 %)	659 (+ 84 %)

Table 15: Estimated sales for the complete ELV scope, Green Constraint scenario

This summary of the cumulative business volume of the various used parts contributions shows:

- Overall growth in activity compared with the 2021 baseline: this is the direct impact of the structuring assumption that provides the opportunity for a sharp increase in the reuse rate, for the French fleet or for export; this positive effect is notably visible in the long term;
- A peak in economic activity around 2035, due to the combination of:
  - a flow of ELV that is still predominantly thermal, with very strong associated demand;
  - the volume of electrified ELV is already significant, and the economic contribution is even greater—around 35%—due to very strong demand for all types of parts and for specific components with high economic potential, including, but not limited to, the mobility battery.

However, it is important to interpret the underlying assumptions for the parts resale business in order to put the aggregated figures into perspective:

- The opportunity for a significant overall increase in the rate of reuse—irrespective of the type of ELV—must be turned into an economic reality, which means financing an increase in parts dismantling capacity and working on ways to improve resale channels (domestically or for export);
- The reversed dynamics of the flow of thermal and electrified ELV—and of the corresponding fleets—will make it even more complex to meet demand in practice;
- Lastly, the projected figures for mobility batteries sold by the ELV sector require a diagnostic autonomy that has not been established in the current framework (also applicable to the specific case described in the following section).

Note: the contribution in used parts for reuse from ICE and transmissions from the thermal part of the powertrain for the Hybrid family is not included here: Firstly, even in the simpler current case of thermal ELV for an ICE fleet, dismantling rates are fairly low (20 to 30%[40]), for contained resale prices; secondly, the projected volumes of hybrid ELV are fairly low by 2035 (around 7%), and only significant from 2040 onwards (23%); lastly, the wide disparity in hybrid architectures makes it complex and uncertain to match dismantled parts to demand. This activity will nevertheless continue but will remain small compared to the other components of the reuse economy described in this section.

6.3.1.2. Residual dismantled parts requiring intervention or for material recovery

Within this perimeter, the study focused solely on the differences linked to the specific aspects relating to the motorization of electrified vehicles (see Table 7). In contrast to the previous chapter on used parts, the scope for material recovery outside the powertrain is well known.

[40] STUDY OF THE NON-METALLIC CONTENT OF REUSED PARTS EXTRACTED FROM END-OF-LIFE VEHICLES, ADEME, 2014

For disassembled parts, everything that is not sold as a directly functional part (possibly with minor intervention)—as defined in the previous section—is sold in another way:

- either still as a component, but in a condition that no longer directly permits its original function (except in the specific case of the battery, see below): in this case, it is a matter of repurposing (using the battery as stationary energy storage, for example) at a reduced price because there are significant additional costs associated with in-depth and/or complex work: for example, the dismantling of battery packs to repair certain components, or even replace certain cells and then reconditioning so that the whole unit regains its physical integrity and an acceptable performance;
- or in the form of recovery of secondary raw materials depending on their composition.

RESALE OF PARTS FOR REPURPOSING

The following assumptions have been made for:

- the mobility battery, at 20% of the new price instead of 60%;
  Note: in the specific case of the battery, it is considered that the case of remanufacturing—for the original application, i.e. electric mobility—is covered by the approach chosen here, due to the very high cost of intervention on the pack and its sub-components;
- the hydrogen tank, at 50% of the new price instead of 75%;
- the fuel cell and its integration system, at 25% of the new price instead of 50%.

The tables below show the projected repurposing prices associated with these assumptions.

	Battery Pack
2025	
Capacity kWh	25,240
Value - EUR	828,489
2030	
Capacity kWh	62,381
Value - EUR	1,354,980
2035	
Capacity kWh	4,003,345
Value - EUR	64,253,084
2040	
Capacity kWh	15,350,948
Value - EUR	225,955,774

	Fuel Cell Systems	H2 Tank
2025		
Value - EUR	/	/
2030		
Value - EUR	6,299	5,875
2035		
Value - EUR	30,717	38,132
2040		
Value - EUR	1,258,285	1,765,468

Table 16: Repurposing price projections associated with specific components, Green Constraint scenario

As fuel cell vehicles have only recently appeared on the market and in very limited numbers compared with BEV, there are no associated ELV before 2028 (modelling shows only three in that year for these architectures).

As far as mobility batteries are concerned, large capacities (in kWh) are available for repurposing—or remanufacturing in other words—because of the assumptions made (see previous section), in particular:

- little possibility of direct reuse without major intervention (10%), due to the demands of automotive use;
- lower durability (currently 15 years).

However, even with a reduced residual price for remanufacturing—from 60% of the new price to 20%—the business volume is substantial, especially from 2035 onwards, with potential sales of around €64 million.

Note: there is significant uncertainty on this point, due to the fact that there is currently virtually no market for the recycling of mobility batteries. It is therefore important to note that the assumption made at this stage regarding the reuse price is a major element of volatility in the valuation of this component, and more generally in the economic activity associated with electrified ELV, given the amounts considered. In fact, by increasing the remanufacturing price from 20% to 30% of the new price, the potential number of sales in 2035 would reach €96 million.

Special case of the catalytic converter / DPF

Among electrified vehicles, all hybrid configurations with an ICE continue and will continue to have a catalytic converter or diesel particulate filter (DPF), in compliance with pollution control regulations and requirements. From the point of view of economic activity, even if reuse is possible, most of these parts are treated for material recovery: for a clearer understanding, 100% material recovery has been considered, for a price per component of EUR 60. Based on the number of hybrids ELV available in each timeframe, the following estimate has been established:

	2025	2030	2035	2040
Hybrid ELV (*number per year)*	4,911	12,222	97,582	317,661
Catalytic converter / DPF sales (millions of euros)	0.3	0.7	5.9	19.1

Table 17: Estimated specific sales of Catalytic converter/APF, Green Constraint scenario

Recovery of materials

When it is not possible to reuse the part directly or to repurpose it, the parts are recovered on the basis of their potential for secondary raw materials. In this case, an analysis of the material composition has been conducted for the various parts concerned on the basis of the material sheet (see example given earlier for the electric motor in Table 9). The following parameters were applied:

- mass ranges (+/- 10% around an average value);
- depending on the power of the electrification of the vehicle (for example, a 100 kW electric motor will contain more material than a 70 kW motor).

From an economic point of view, we need to differentiate between two possible methods of part processing for material recovery, once the ELV has been dismantled:

- **simple pre-sorting by part type** (see the categories of the powertrain architectures identified in Table 7) for which the recovery projections are detailed below;
- **complete or almost complete dismantling** of these pre-sorted parts into basic single-material components: in this case, upon resale to specialist recyclers, and

depending on the part in question, **prices can be 2 to 5 times higher than for pre-sorting**.

To estimate the figures for the activity associated with simple pre-sorting, revenues have been calculated on the basis of index quotations for main generic parts from Usine Nouvelle[41], or typical purchase prices from scrap merchants:

Parts	EUR / ton (2023)
High voltage cables / Index N1354	1,700
Aluminium housings / Index N1370	900
Stainless steel / average purchase price	800
Electric motors / Index N1355	500

Table 18: Reference purchase price for pre-sorted parts, Green Constraint scenario

	HV cables (N1354)		Carters Alu. (N1370)		Stainless steel (average)		Electric motors (N1355)	
	/ min	/ MAX	/ min	/ MAX	/ min	/ MAX	/ min	/ MAX
2025								
Mass - kg	12,177	14,883	163,827	200,233	32,639	39,893	109,219	133,490
Value - EUR	20,701	25,301	147,444	180,210	26,112	31,914	54,609	66,745
2030								
Mass - kg	30,646	37,457	412,168	503,761	82,876	101,293	284,779	348,063
Value - EUR	52,099	63,676	370,952	453,385	66,301	81,035	142,389	174,032
2035								
Mass - kg	1,562,054	1,909,178	6,964,626	8,512,320	1,221,212	1,492,592	4,164,115	5,089,474
Value - EUR	2,655,493	3,245,602	6,268,163	7,661,088	976,970	1,194,074	2,082,057	2,544,737
2040								
Mass - kg	7,325,719	8,953,657	24,719,451	30,212,662	4,905,661	5,995,807	16,744,549	20,465,560
Value - EUR	12,453,723	15,221,217	22,247,506	27,191,396	3,924,528	4,796,646	8,372,274	10,232,780
Total Mass - kg	**8,930,597**	**10,915,174**	**32,260,072**	**39,428,977**	**6,242,388**	**7,629,586**	**21,302,661**	**26,036,586**

Table 19: Potential material recovery from electrification parts, Green Constraint scenario

Note: this estimate of material recovery by simple pre-sorting does not therefore cover the entire scope of the items listed previously (see Table 13), in particular due to the fact that certain resale activities do not exist or are not very mature yet (but will become so in the future). With regard to the study of the detailed composition of materials, a complementary point of view is given (see Appendix C).

6.3.1.3. Remaining ELV after dismantling of all parts

At the very end of the chain, once all the components of specific value have been considered, there remains a number of carcasses equal to the volume of ELV at the time horizon in question. Given the relatively stable projections, even up to 2040, there will be no significant reduction from this point of view.

Concerning the recovery of this "unladen" vehicle carcass:

- As far as the Hybrid family is concerned, the case is similar to that of a thermal body—since the requirements for integrating the combustion engine and, more generally, the entire powertrain are the same—with at least as many parts not dismantled as on a combustion engine base, the components specific to

[41] Indices and Quotations: all commodity prices see https://www.usinenouvelle.com/indices/tableaudebord

electrification being added to the conventional ones: the resulting residual mass is therefore at minimum equal, with a similar material composition;
- With regard to the Electric family, as already detailed in the technical section (see Figure 41), even at lower residual mass—which is intended to make the vehicle lighter—the material content is more valuable.

In either case, the overall valuation is expected to be at least equivalent or even slightly higher, with no significant impact on this economic activity .

Note: the position taken here is not to analyze the current situation of pure electric ELV—which are generally chassis of thermal origin that are best adapted to new requirements—but rather to look ahead to the medium term, when the BEV that will become ELV will already meet the new design standards on which the various assumptions are based (particularly in terms of vehicle weight reduction).

6.3.1.4. Overall results

Based on the various models and projections, the overall trends in economic activity for the industry as a whole over the various time horizons from 2025 to 2040 are as follows:

- a sharp increase in the **resale of used parts**—from EUR 357 per ELV in 2021 to double that in 2035 (EUR 715 per ELV)—as a result of the growing interest in the circular economy;
- a burgeoning business in the **resale of mobility batteries** after servicing (via remanufacturing or for reuse), which could reach around EUR 64 million by 2035 (assumption based on 20% of the projected price per new kWh);
- a significant additional contribution in proportion to the **materials recovery by simple pre-sorting of parts** specific to electrification—again because of their composition—already estimated in 2035 at almost EUR 27 million, or EUR 141 / ELV-e/h;
- the value of ELV carcasses is at minimum maintained.

The table below provides a more operational point of view, for the various sub-activities of a "generic" ELV center, of the impacts expected to support the changes in economic activity described in this section (and summarized above):

Sub-activities of the ELV center	Medium/long-term impact on the bottom line (*Estimated per ELV*)	Comments
Collection of end-of-life vehicles	negative	Costs expected to rise as a result of regulatory requirements
Compulsory operations	negative	Specific costs: High voltage and battery management in particular
Dismantling used and other second-hand parts:	up sharply overall	In line with the expected increase in the resale of used parts, with greater ELV-e/h complexity
• *Non- powertrain items*	*on the rise*	*Growing demand for used parts*
• *Heat engine & Transmission*	*negative*	*Reducing the needs of the thermal fleet*

Sub-activities of the ELV center	Medium/long-term impact on the bottom line (*Estimated per ELV*)	Comments
• *Electrification elements*	*positive*	*Growth in demand for electricity*
• *Mobility battery*	*positive*	*Based on diagnostic capabilities*
Dismantling materials for recycling, sales and stock management	negative	No more "electrified" elements to be dismantled for material recovery before shredding
Catalytic converter	slightly negative	Only for ELV-h
Other high added value elements	positive	Electrification elements
Carcass	stable	/
Administrative and accounting management of the ELV processing business	negative	In line with the expected increase in activity, with, in particular, a greater diversity of "products" to be managed, particularly in relation to ELV/h

Table 20: Comparative trends in the operation of an ELV Center

In addition to the reversal in the dynamics of the combustion and electrified fleets, the 15-year timeframe targeted by the study highlights the future complexity for the industry in seizing opportunities for economic development during this transition period, due to the necessary changes in the current operation of ELV treatment and due to a much greater diversity of vehicle types.

6.3.2. Training and investment in ELV centers

6.3.2.1. Summary

It is estimated that, for the entire sector (i.e. around 1,700 approved ELV centers[42]), the total investment cost over the period 2022-2040 will be **EUR 20.5 million (i.e. an average of EUR 12,058 per ELV center),** of which:

- EUR 3.8 million is dedicated to training staff in battery removal;
- EUR 3.3 million for training in battery diagnostics;
- EUR 10.1 million for battery removal equipment;
- EUR 2.9 million for battery diagnostic equipment.

This annualized cost would therefore be EUR 1.1 million per year (or EUR 647 per ELV center per year).

The sections below present the general principles of this modelling as well as the assumptions and data used to calculate the various costs.

6.3.2.2. General principles of modelling

OBJECTIVE

The aim of this section is to give an order of magnitude for the investment required by the sector (all ELV centers) for the treatment of ELV-e and ELV-h, and to present the weight of each investment component.

SCOPE

The significant investments that ELV centers will have to make as part of the electrification of their fleets cover two main areas:

- training staff to remove and diagnose batteries;
- battery removal and diagnostics equipment.

Note: the "battery diagnostics" sections only concern ELV centers that seek to recover batteries through reuse or repurposing.

No estimate has been made of the investment required to develop the existing land and infrastructure. The justifications for this choice are presented below.

- The car fleet is not expected to grow between now and 2040 (see section 5.2.1.1). There would not be a surplus of electrified ELV compared with the ELV currently received, but rather a replacement of thermal ELV by electrified ELV. Consequently, the size of the ELV centers would not have to increase. It should be noted that this assumption is only realistic if future regulations do not impose differentiated storage spaces (thermal, electrified, electrified involved in accidents, etc.).
- The investment needed to develop battery storage areas with charging and discharging facilities (in conjunction with the development of the reuse and repurposing sectors) is uncertain. Indeed, there is a lack of visibility on the regulations governing battery management and on the profitability of these sectors... However, if these investments (probably substantial —millions of euros)

[42] According to some industry representatives, the number of ELV centers is likely to fall between now and 2040, rather than remain constant as assumed in the report. It should be noted that the reduction in the number of ELV centers does not necessarily imply a reduction in activity; rather, it is linked to the number of ELVs to be processed per center (the number of which will fall slightly between now and 2040). It can be assumed that the decline in the number of ELV centers will be accompanied by an increase in their size. The impact of this dynamic on the calculation is considered to be zero (e.g. the investment of two small ELV centers with an average of one bridge per center is equal to the investment of one large ELV center with an average of two bridges).

were to be made, they would probably only concern a small number of ELV centers by 2040.

In addition, investment in risk management for electrified ELV has not been modelled because of the very wide gap between the costs of different risk management solutions and the uncertainty surrounding their application to ELV centers. As a reminder (see section 4.1.2.2.7), damaged electric batteries can present an increased risk of fire and several solutions can be implemented by ELV centers, which involve different costs:

- Implementation of a "quarantine" procedure for at-risk electrified ELV, where they are stored in a dedicated area before being processed at no significant cost (installation of signage and reorganization of areas);
- storage of the battery or the electrified ELV on a "water tank", where, in the event of a fire, the ELV or the battery is submerged; low investment estimated at around EUR 5 000 / tank;
- storage in a fireproof container at an estimated cost of around ten thousand euros per container;
- storage of electrified ELV or batteries in dedicated warehouses, at a cost of several thousand euros per center[43] .

Staff training entails a cost directly linked to the training (trainers' fees, teaching materials, etc.) but can also entail an opportunity cost[44] linked to the fact that staff undergoing training do not work during the training days. During the training days, the staff cannot conduct their dismantling and spare parts reuse activities (if applicable) and the ELV center therefore suffers a loss of income. However, this opportunity cost is not considered in the estimated training costs because it is assumed that the ELV centers will conduct this training during relatively slower periods and therefore during which the opportunity cost is lower or even zero.

DISCOUNTING FUTURE COSTS

Money does not have the same value over time because of the uncertainty and risks associated with economic activities: a unit of money today is worth more than the same unit of money in the future. This principle is generally known as the "time value of money". Future investments must therefore be discounted to their present value. This is done by calculating the Net Present Value (NPV), which is given by the following relationship:

$$NPV = \sum_{n=1}^{T} \frac{A_n}{(1+q)^n}$$

Where:

- A_n is total investments in year n;
- q is the discount rate;
- n is the period; T is the total number of years until 2040.

Investments are therefore calculated for each year and then discounted (i.e. multiplied by the discount factor corresponding to the year in question). For this study we have used a discount rate of 5%[45] .

[43] The cost of warehouses depends on the surface area. We have estimated this cost using a construction cost of 1,000 EUR/m² based on data found on dedicated sites. Related links
https://travaux.mondevis.com/construction-entrepot/guide/
- https://www.travaux-maconnerie.fr/cout-construction-entrepot-m2

[44] The opportunity cost of an economic action or decision is the measure of the value of each of the other actions or decisions foregone.

[45] Based on discussions on the discount rate in the evaluation of public investment projects Commissariat général à l'Investissement, France Stratégie and the Conseil général de l'Environnement et du Développement. Link: https://www.strategie.gouv.fr/debats/taux-dactualisation-levaluation-projets-dinvestissement-public#:~:text=Since%202003%2C%20the%20Office%20of,social%20de%20pr%C3%A9f%C3%A9rence%20to%20time.

The modelling principles for estimating the orders of magnitude of the components described above are described in greater detail in the following sections.

6.3.2.3. Training staff to remove batteries

6.3.2.3.1. Modelling principles

Two levels of training have been modelled:

- Basic training to obtain authorization to work on live equipment (such as B2TL or B2XL training in accordance with standard NF C 18-550) which, according to the people interviewed, is sufficient for operations involving the removal of batteries that have not been damaged;
- Advanced training for work on damaged batteries.

Basic training will be relatively more widespread in ELV centers than advanced training, as the vast majority of ELV centers will need to be able to drop off batteries or consign them[46] to facilitate a potential transport (for example, if electric or hybrid ELV are sent to another ELV center for treatment).

On the other hand, advanced training will be less widespread, as the proportion of electric vehicles involved in accidents will eventually be lower than the proportion of vehicles at the end of their life, so there will be less need for ELV centers with staff with this level of training.

Training will have to be repeated at regular intervals due to staff turnover and the need for ongoing training. It is assumed that the number of ELV centers that will train staff each year will increase gradually over the period 2022-2040 (the estimated proportions for each year are presented in the appendices); this is consistent with the linear increase in the proportion of electric and hybrid vehicles in the French vehicle fleet (see Figure 36).

The assumptions and data used to calculate staff costs over the period 2022-2040 are shown in Table 21.

Data	Value	Unit	Source
Average number of people trained per ELV center with basic training	2	Person per ELV center	RDC Environment assumption based on survey results (see section 4.3.2.6).
Average number of people trained per ELV center with advanced training	1	Person per ELV center	RDC Environment assumption
Renewal period for both courses	2	Year	RDC Environment assumption
Cost of basic training	500	EUR per person	Survey results (see section 4.3.2.6)
Cost of advanced training	1,000	EUR per person	High end of training costs reported by ELV centers via the survey.
Proportion of ELV centers with staff trained in basic skills by 2040	90	%	RDC Environment assumption based on survey results (see section 4.3.2.6) and the number of approved ELV centers in France according to ADEME (1,700).

[46] Electrical consignment is a procedure designed to minimize electrical risks.

Data	Value	Unit	Source
Proportion of ELV centers with staff trained in advanced training by 2040	50	%	RDC Environment assumption

Table 21: Assumptions and data used to calculate training costs

6.3.2.3.2. Results

The total discounted investment cost for staff training over the period 2022-2040 for the entire sector is estimated at around **EUR 3.8 million (i.e. an average of EUR 2,235 per ELV center)**, or an average annual cost of **EUR 0.2 million (i.e. an average of EUR 117 per ELV center per year)**:

- EUR 3 million for basic training;
- EUR 0.8 million for advanced training.

The results for each year are presented in the appendices (see Table 27 in appendices).

6.3.2.4. Battery diagnosis training

6.3.2.4.1. Modelling principles

Training will have to be repeated at regular intervals due to staff turnover and the need for ongoing training. It is assumed that the number of ELV centers that will train staff each year will increase gradually over the period 2022-2040 (the estimated proportions for each year are presented in the appendices). By 2040, it is assumed that the proportion of ELV centers with staff trained in battery diagnostics will be equal to the proportion of ELV centers reusing spare parts today, i.e. around 70% of ELV centers in France.

The assumptions and data used to calculate the costs of battery diagnosis training are shown in the table below.

Data	Value	Unit	Source
Average number of people trained in diagnostics by 2040 per ELV center performing diagnostics.	1	Person per ELV center	RDC Environment assumption based on the proportion of ELV centers that currently have a reuse activity (~70%).
Renewal period for diagnostic training	2	Year	RDC Environment assumption based on discussions with industry players (study monitoring committee meeting on 29/11/2022).
Cost of diagnostic training	1,000	EUR per person	RDC Environment assumption based on discussions with industry players (study monitoring committee meeting on 29/11/2022).
Proportion of ELV centers with staff trained in battery diagnosis by 2040	~70	%	RDC Environment's assumption based on the proportion of ELV centers that currently have a reuse activity (~70%).

Table 22: Assumptions and data used to calculate the investment costs of developing diagnostic capacity - diagnostic training

6.3.2.4.2. Results

The total discounted investment cost of training staff to diagnose batteries over the period 2022-2040 for the entire sector is estimated at around **EUR 3.3 million (or an average cost of EUR 1,976 per ELV center),** or an average annual cost of **EUR 0.2 million (or an average of EUR 117 per ELV center per year)**.

The results for each year are presented in the appendices (see Table 29 in appendices).

6.3.2.5. Battery removal equipment

6.3.2.5.1. Modelling principles

The modelling was based on the current battery removal procedure (see section 4.1.2.2).

The additional equipment required for the treatment of ELV-e and ELV-h that has been modelled is as follows:

- bridges allowing access under the vehicle chassis;
- lifting tables.

Other equipment such as forklift trucks and personal protective equipment has not been included in the calculation. It is assumed that this equipment is already present in the vast majority of ELV centers and therefore does not represent an additional investment linked to the electrification of vehicles.

The investment cost is estimated for ELV centers that do not yet have this equipment and for ELV centers that do have it but will have to replace it when it reaches the end of its life.

The results of the national survey of all approved ELV centers provide an indication of the extent to which ELV centers are equipped with lifting cranes and tables (see section 4.3 and table below).

It is assumed that the number of ELV centers that will install this equipment each year will increase gradually over the period 2022-2040 (the estimated proportions for each year are presented in the appendices); this is consistent with the linear increase in the proportion of electric and hybrid vehicles in the French vehicle fleet (see Figure 36).

The assumptions and data used to calculate the cost of battery removal equipment are presented in the table below.

Data	Value	Unit	Source
Average number of decks per equipped ELV center	1	bridge per ELV center	RDC Environment assumption based on survey results (see section 4.3.2.7)
Average number of lifting tables per equipped ELV center	1	table per ELV center	RDC Environment assumption based on survey results (see section 4.3.2.7)
Average cost of bridges	6,000	EUR per unit	Interviews with ELV centers and discussions with other players in the sector (follow-

Data	Value	Unit	Source
			up committee for this study on 29/11/2022).
Average cost of lifting tables	6,000	EUR per unit	Interviews with ELV centers
Service life of cranes and lifting tables	15	Year	RDC Environment assumption based on internet research[47]
Proportion of ELV centers equipped with a lifting table by 2040	~50	%	RDC Environment assumption based on discussions with industry players (study monitoring committee meeting on 29/11/2022).
Proportion of ELV centers equipped with a bridge by 2040	~50	%	

Table 23: Assumptions and data used to calculate equipment investment costs

6.3.2.5.2. Results

The total discounted investment cost for battery removal equipment over the period 2022-2040 for the entire sector is estimated at around **EUR 10.1 million** (an average of EUR 5,941 per ELV center), including EUR 6.3 million for bridges and EUR 3.7 million for tables, or an average annual cost of **EUR 0.5 million** (an average of EUR 294 per ELV center per year).

The results for each year are presented in the appendices (see Table 28 in appendices).

6.3.2.6. Battery diagnostic equipment

6.3.2.6.1. Modelling principles

[47] Link to the website https://conseils.hellopro.fr/faq-sur-les-ponts-elevateurs-1063.html#:~:text=Certain%20ponts%20%C3%A9l%C3%A9vators%20may%20be%20s,that%20maintenance%20of%20the%20bridge.

Modelling the industry's investment to develop diagnostic capability includes the acquisition of an interface (electronic equipment) that provides access to information on the SoH of the battery when it is removed.

According to manufacturers, the need for battery diagnostic interfaces is likely to diminish over time, as vehicles and their IT systems will increasingly be able to perform self-diagnostics[48]. In other words, vehicles will become their own diagnostic interface. However, to avoid underestimating investment requirements, it is assumed that ELV centers will gradually acquire diagnostic capacity over the period 2022-2040 (the proportions of ELV centers with a diagnostic interface estimated for each year are presented in the appendices).

By 2040, it is assumed that the proportion of ELV centers with a battery diagnostic interface will be equal to the proportion of ELV centers that reuse spare parts today, i.e. around 60% of ELV centers in France.

The assumptions and data used to calculate the cost of the equipment required to conduct battery diagnostics are shown in the table below.

Data	Value	Unit	Source
Average number of diagnostic interfaces by 2040 per ELV center performing diagnostics.	1	Equipment per ELV center	RDC Environment's assumption based on the proportion of ELV centers that currently have a reuse activity (~70%).
Diagnostic interface depreciation period	10	Year	Interview with a car manufacturer
Average cost of diagnostic interfaces	Basic case: 3,000 Minimum: 1,000 Maximum: 5,000	EUR per piece of equipment	Interview with a car manufacturer and discussions with other players in the sector (follow-up committee for this study on 29/11/2022)
Proportion of ELV centers with a diagnostic interface by 2040	~70	%	RDC Environment's assumption based on the proportion of ELV centers that currently have a reuse activity (~70%).

Table 24: Assumptions and data used to calculate investment costs for diagnostic interfaces

[48] Based on discussions with French carmakers.

6.3.2.6.2. Results

The total discounted investment cost for the interfaces used to diagnose batteries over the period 2022-2040 for the entire sector is estimated at **EUR 2.9 million** (or EUR 1,719 per ELV center on average), or an average annual cost of **EUR 0.16 million** (or EUR 95 per ELV center per year on average).

The results for each year are presented in the appendices (see Table 29 in appendices).

7. Conclusions

ASSESSMENT OF THE LEVEL OF PREPAREDNESS OF THE ELV TREATMENT SECTOR

1) Overview of the ELV-e and ELV-h management sector

The ELV management sector is facing the beginning of the transition from thermal cars to 100% electric or hybrid cars (i.e. electrified vehicles). For the time being, the number of electric and hybrid vehicles arriving at ELV centers is marginal:

- in the majority of cases, they are vehicles which have been involved in an accident or "written-off", i.e. which are technically irreparable or for which the cost of repair exceeds the residual value of the vehicle;
- and a minority are vehicles at the end of their life, i.e. vehicles with low residual economic value that the owner wishes to dispose of.

The management of electrified ELV requires processes to be adapted, mainly in relation to the management and removal of electric batteries. Removing electric batteries requires dedicated equipment and, above all, training and accreditation of personnel in dealing with electrical equipment. Once the batteries have been removed, if ELV centers are to determine their residual economic value, they need to be able to diagnose the battery's SoH. This diagnosis also requires the development of in-house skills and dedicated equipment. It should be noted that existing training covers situations where electrified ELV have not been involved in accidents; for electrified ELV that have been involved in accidents, existing training is not sufficient.

2) Results of the national survey of all approved ELV centers

The majority of ELV centers have not yet received electric or hybrid vehicles, but they are preparing to do so. In fact, just over half of the ELV centers surveyed said that they have the information they need to receive these vehicles, and almost half have already trained their staff to remove the traction batteries, an important step in the treatment of these vehicles. In addition, around a third of the centers are planning to train their staff in battery removal. These answers indicate that ELV centers are preparing for the arrival of these new types of vehicles.

The key messages from the survey of ELV centers are as follows:

- More than half of the ELV centers responding to the survey (62%) said that they had never been confronted with the reception of an ELV-e or ELV-h;
- Of the 38% of ELV centers that said that they had already had to receive an ELV-e or ELV-h, the majority (75% of these centers, i.e. 28.5% of respondents) said that the delivery went smoothly thanks to their in-house knowledge;
- Nearly 55% of ELV centers surveyed said that they would not accept an ELV-e or ELV-h at their centers at present;
- Nearly 40% of the ELV centers surveyed predict that the increase in the number of ELV-e and ELV-h will have a negative economic impact on their business, particularly because of the difficulty of managing and recovering electric traction batteries;
- Nearly 50% of ELV centers surveyed said that they currently have staff trained in removing traction batteries from ELV-e and ELV-h, and nearly 30% said they plan to train their staff;
- Around 15% of ELV centers say they have access to the information and/or IT tools needed to diagnose the SoH of the traction battery;
- With regard to the equipment and tools required to remove a battery:
    - 61% of the ELV centers surveyed already have a bridge that hooks onto the vehicle's support points, allowing access to the entire chassis from below (such as a two-post bridge);
    - 11% of ELV centers surveyed currently have lifting tables and 9% have a similar mechanism;
    - 34% of the ELV centers surveyed already have insulated tools and 30% are planning to acquire them.

CHANGES IN THE VEHICLE FLEET AND ELV FLOWS

- In the short term (2025-2030), the volume of electrified ELV will remain low, allowing the industry to prepare for the future;
- Because of the inertia of fleet renewal, the flow of thermal and electrified ELV will not be close to parity until 2040, when the thermal fleet will be in sharp decline and the electrified fleet in clear majority;
- However, the possible diversity of electrified engine architectures and associated powertrains—some of which are still combustion-based—is another major factor in the transition that needs to be considered in the preparation and organization of ELV processing centers.

ECONOMIC CONSEQUENCES AND IMPACT

1) Resale of used parts and material recovery

Based on the various models and projections, the overall trends in economic activity for the industry as a whole over the various time horizons from 2025 to 2040 are as follows:

- a sharp increase in the **resale of used parts**—from EUR 357 / ELV in 2021 to double that in 2035 (EUR 715 / ELV)—as a result of the growing interest in the circular economy;
- a burgeoning business in the **resale of mobility batteries** after servicing (via remanufacturing or reuse), which could reach around EUR 64 million by 2035 (assumption based on 20% of the projected price per new kWh);
- a significant additional contribution in proportion of **materials recovery by simple pre-sorting of parts** specific to electrification—again because of the composition

of these components—already estimated in 2035 at almost EUR 27 million, i.e. EUR 141 / ELV-e/h;
- the value of ELV carcasses is at least maintained equal.

In addition to the reversal in the dynamics of the thermal and electrified fleets, the 15-year timeframe targeted by the study highlights above all the future complexity for the industry to seize opportunities for economic development during this transition period, due to the necessary changes in the current operation of ELV treatment and to a much greater diversity of vehicle types.

2) Investment in staff training and equipment

The electrification of the vehicle fleet will force ELV centers to adapt to the new steps required to process electrified ELV. This will require investment in staff training and in the equipment needed to conduct these new steps. It is estimated that, to process all electrified ELV, the total investment cost for approved centers over the period 2022-2040 would amount to **EUR 20.5 million** (an average of EUR 12,058 per ELV center), of which:

- EUR 3.8 million are dedicated to training staff in battery removal;
- EUR 3.34 million are for training in battery diagnostics;
- EUR 10.1 million are for battery removal equipment;
- EUR 2.96 million are for battery diagnostic equipment.

This annualized cost would therefore be EUR 1.1 million per year (or EUR 647 per ELV center per year).

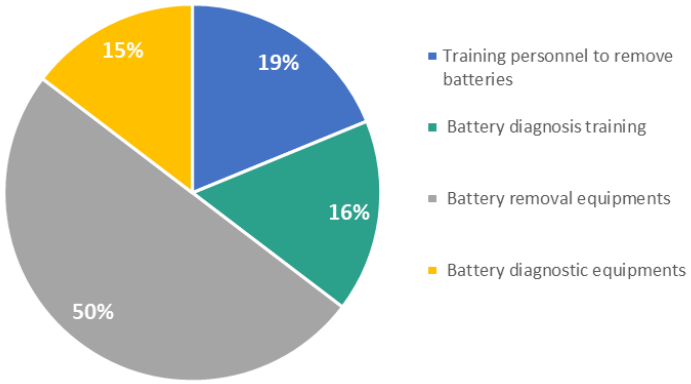


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GLOSSARY

Removing a battery [1]	Disconnecting, detaching and removing the battery from the vehicle.
Preparation for reuse [3]	Any inspection, cleaning or repair operation with a view to recovery, whereby products or components of products that have become waste are prepared for re-use without further pre-treatment.
Repurposing [2]	Any operation that results in parts or the complete battery being used for a different purpose or application than the one that the battery was originally designed for
Remanufacturing [2] and [4].	Remanufacturing is a rigorous and standardized industrial process[49] which enables a used part or product to be returned to a state of performance and functionality equivalent to or even superior to that of the original, for the same use. This process enables parts/products to be refurbished to a uniform level of quality and performance from the first to the last. For electric batteries: Any technical operation on a used battery that includes the disassembly and evaluation of all its battery cells and modules and the use of a quantity of battery cells and modules, new, used or recovered from waste, or other battery components, to restore the capacity of the battery to at least 90% of the original rated capacity, and where the SoH of all individual battery cells is consistent, differing by no more than 3% from each other, and results in the battery being used for the same purpose or application for which the battery was originally designed.
Reuse [2]	Any operation by which products or components that are not waste are reused for the original purpose for which they were conceived.

[1] - RDC Environment.

[2] - Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL concerning batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) No 2019/1020.

[3] - Directive 2008/98/EC.

[4] - BONJEAN Anne-Charlotte (ADEME), WHITWHAM Marguerite (Philgea), TREBESSES Gabrielle (Moringa), ZWOLINSKI Peggy (INP Grenoble), ROCCHI Valérie (INP Grenoble) 2023. Study on remanufacturing. 55 pages.

[49] Where standardized means "which eliminates variations in the operational process in order to achieve uniform components/products in terms of quality and performance".

ABBREVIATIONS AND ACRONYMS

ADEME	French Agency for Ecological Transition
BEV	Battery electric vehicle
BMS	Battery Management System
DPF	Diesel particulate filter
ELV	End-of-life vehicle
ELV-e	End-of-life electric vehicle
ELV-h	End-of-life hybrid vehicle
EPR	Extended Producer Responsibility
EREV	Electric vehicle with range extender (Extended Range EV)
EVEC	Electric Vehicle Expert Center
GC	Green Constraint (script)
GDP	Gross Domestic Product
GG	Green Growth (scenario)
GHG	Greenhouse gas
HEV	Hybrid electric vehicles
ICE	Internal Combustion Engine
IDIS	International Dismantling Information System
LCV	Light commercial vehicles
LV	Light vehicles
MHEV	Light Hybrid Electric Vehicles
MR	Motorization Rate
NPV	Net Present Value
PFCV	Plug-in hybrid fuel cells vehicle
PHEV	Plug-in Hybrid Electric Vehicle
PPE	Personal Protective Equipment
PV	Private vehicles
SoH	State of Health
TCO	Total cost of ownership
VOCS	Volatile organic compounds
WAPO	World Automotive Powertrain Outlook
ZEV	Zero-Emission Vehicle

APPENDIX A: KEY CONCEPTS IN ELECTRIC MOBILITY BATTERIES

Lithium-ion batteries (LIBs) have established themselves as the battery of choice for electric vehicles due to their high energy and power density, low weight and long life. This is because this chemistry has the highest redox potential (E0(Li+/Li) = -3.04V), making it the component of choice for battery electrodes. In fact, LIB is becoming the preferred choice in most electric vehicle market segments: 100% electric vehicles, hybrid vehicles, public transport (electric buses), golf carts, etc. Only the public transport sector is still experimenting with a few alternatives (supercapacitors, hydrogen fuel cells, etc.).

In addition, the dominance of LIB favors lower prices due to economies of scale and increases its advantage over other technologies, making it increasingly difficult for a competing technology to emerge in the medium term. On a global scale, only electric mobility solutions on two wheels (electrically assisted vehicles and, to a lesser extent, electric scooters), which are growing significantly in developing countries, can still use lead batteries, for cost reasons.

Still very much a minority in the sector, LIB is starting to compete with lead-acid batteries in lifting and handling equipment, industrial washing equipment and airport ground services. Lastly, in Europe, increased regulatory restrictions on lead-acid batteries and the requirement for cars to limit CO_2 emissions to 95 g/km from 2022 (coupled with financial penalties of EUR 95 per additional g) could encourage the use of LIB technology for starter batteries, thanks to the weight reduction it offers.

LIB technology offers a wide range of uses, using a variety of components to make up the cathode:

- Cobalt-dominant LCO (still used for portable applications, but unlikely to be used on the move);
- Manganese-dominant LMO (replaced LCO in electric and hybrid vehicles);
- Nickel - Manganese - Cobalt: NMC is growing fast (this chemistry ensures good energy density and allows numerous variants which play on the proportions of Ni/Mn/Co and give various gains or losses in energy density or power/charge-discharge/recycling; overall, this technology is currently evolving towards higher and higher nickel contents);
- Nickel - Cobalt - Aluminium: NCA (this is the technology currently used by TESLA for its electric and hybrid vehicle batteries);
- Lithium - Iron Phosphate: LFP (a chemistry which implies a relatively better thermal stability than the chemistries indicated above; it should be noted, however, that the recycling of this chemistry is relatively less profitable because of the materials which can be recovered: iron and phosphorus).

NMC technology is currently in the majority (along with LCO) on portable products.

NMC (41% in 2016), NCA (TESLA, appr. 15%), LFP (used by a number of Chinese manufacturers, notably for electric buses, 35%) and LMO (7%) are the main technologies used in electric and hybrid vehicles.

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APPENDIX B: RECYCLING OPERATIONS FOR ELECTRIC MOBILITY BATTERIES

DISCHARGING BATTERIES

Before dismantling and crushing, the batteries must be completely discharged. There are two methods of discharge:

- Resistive discharge - the batteries are connected to a resistor in such a way as to exhaust its charge. This method is mainly used for industrial batteries arriving in packs.
- Electrolytic discharge - the batteries are submerged in an electrolyte bath. This method is used mainly for large volumes of separate modules or cells (where individual connection of each module/cell to a resistor is not feasible) or when the packs are damaged.

REMOVAL

At present, batteries are dismantled manually, removing the screws and bolts, the WEEE components, the wiring, the BMS and the battery shell (made of aluminium or scrap metal). Dismantling is necessary because shredders are not (at this stage) suitable for shredding all the components. The size of the shredder 'mouth' and the shredding force are not sufficient. It should be noted that dismantling is not a systematic stage in the sector; some players process non-dismantled batteries in their furnaces via pyrolysis.

Dismantling is currently done manually because:

- batteries come in different sizes and designs;
- incoming volumes do not currently justify investment in an automated solution.

There is little or no standardization when it comes to battery design. It is common for a car manufacturer to have between five and 10 different battery models, depending on the type of car, the power output, and so on. Additionally, battery waste streams are currently small, which means that automated dismantling is not yet possible.

SHREDDING

Shredding is conducted in batches, depending on the chemistry of the batteries being processed (cells or modules), in order to maintain control and visibility over the composition of the shredded material.

The batteries go through two shredding stages. The first shredding is conducted in enclosed and sealed shredders, during which gases and VOCs are captured and filtered. The second shredding stage further reduces the granulometry of the shredded material, which is then separated into three fractions by mechanical separation using sieves, magnets, etc.:

- black mass,
- paper/plastic and
- scrap metal.

Paper/plastic is incinerated with recovery of electrical energy since there are too many variations in composition to recycle it. Scrap metal is recycled.

The black mass is placed in "big bags". Each big bag is systematically analyzed in a laboratory to direct it towards the best recycling route. Depending on the cobalt content (the main but not the only decision criterion), the black mass will be processed in France (if the level is low) or in Asia (if the level is high).

REFINING

The black mass will then be processed using two main refining methods: pyrometallurgy and/or hydrometallurgy.

Pyrometallurgy is a thermal metallurgical process used to separate and recover metals. The process consists of three stages:

- heat treatment to homogenize the metal source (roasting);
- chemical reaction (oxidation) allowing separation;
- refining.

When Li-ion batteries are recycled, they are processed in a high-temperature foundry (at temperatures higher than 1,000°C), which transforms metal oxides into their metallic form (a molten metal alloy) depending on the elements present. This alloy is refined for use in new battery cathodes (e.g. cobalt and nickel). A slag, which contains lithium, remains and it is often used in concrete applications. At present, pyrometallurgy seems to be the focus of large-scale recycling activities and hydrometallurgy is only used on a small scale. In fact, pyrometallurgy is the most advanced and, historically, the most widely used process for recycling used batteries.

Hydrometallurgy is a metal extraction technique that includes a step in which the metal is solubilized to enable it to be purified. It is a liquid metal treatment process, hence the name hydrometallurgy. It consists of dissolving the various metals contained in an ore or concentrate in order to separate them for recovery.

The first step is to dissolve the black mass powder in an acid bath (leaching). Once the mixture has been filtered, two technologies are used industrially to separate the active ingredients from the concentrate. The first, liquid-liquid extraction, involves mixing the leaching solution with an immiscible organic solvent. The second method, precipitation, involves varying two parameters to separate the materials: temperature and pH.

Although hydrometallurgy produces finished products of greater purity than pyrometallurgy, it is more costly to manage (EUR 200-400/ton for pyrometallurgy, twice that for hydrometallurgy).

APPENDIX C: INTRINSIC MATERIAL RECOVERY FOR SPECIFIC ELECTRIFICATION COMPONENTS

With a different approach to materials recovery by parts as explained above (see 6.3.1.2), this time based on detailed material composition, a macroscopic estimate of the intrinsic value of dismantled components can also be made on the basis of the intra-European exchange prices for sorted/shredded waste presented in the table below. This section is therefore for information purposes—not to be confused with the (almost) complete dismantling analyzed in the body of the report.

The economic values in EUR per ton in the table below correspond to the ratio between the economic values and the quantities of waste traded between France and its European trading partners. More precisely, it is the average between the price per ton exported and the price per ton imported. The products traded, including certain waste types, are declared using different international classification systems that assign a specific code to a given product. The classification system used here is the Harmonized System (HS).

MATERIAL	EUR / ton (2021)
Copper	3,013
Aluminium	967
Steel	894
Plastics	398
Rubber	233
Ferrous metals	232

Table 25: Intra-European trade prices for sorted/shredded waste (Source: prices deducted from international trade in waste based on Eurostat's COMEX database for France with other EU Member States).

The HS codes used for each subject are as follows:

- Copper: 74.04.00
- Aluminium: 76.02.00
- Steel: 72.04.21
- Plastics: 39.15.90.80
- Rubber: 40.04.00
- Iron: 72.04.29, 72.04.30, 72.04.41, 72.04.49, 72.04.50

Note: due to a lack of robust data, there is no valuation associated with masses for the Electronics and Rare Earths categories.

To illustrate the use of these material prices, in the reference case—powertrain 100 kW, BEV segment C excluding batteries—used previously (see Table 9): the intrinsic value would be EUR 1,350/ton.

The tables below show the projected recoverable mass (in kg) and material recovery associated with specific components for the Green Constraint scenario.

	Copper		Aluminium		Steel		Plastics	
	/ min	/ MAX	/ min	/ MAX	/ min	/ MAX	/ min	/ MAX
2025								
Mass - kg	18,393	22,522	70,517	86,188	52,722	64,438	916	1,155
Value - EUR	55,418	67,860	68,190	83,344	47,134	57,608	364	460
2030								
Mass - kg	47,490	58,147	177,336	216,745	136,555	166,901	2,284	2,880
Value - EUR	143,088	175,198	171,484	209,592	122,080	149,209	909	1,146
2035								
Mass - kg	1,160,274	1,420,968	3,014,548	3,684,447	2,000,590	2,445,166	47,892	60,982
Value - EUR	3,495,906	4,281,375	2,915,067	3,562,860	1,788,528	2,185,978	19,061	24,271
2040								
Mass - kg	5,099,151	6,242,468	10,642,112	13,007,026	8,042,624	9,829,874	167,716	213,705
Value - EUR	15,363,743	18,808,555	10,290,922	12,577,794	7,190,106	8,787,907	66,751	85,055
Total Mass - kg	**6,325,309**	**7,744,105**	**13,904,513**	**16,994,405**	**10,232,492**	**12,506,379**	**218,808**	**278,722**

	Rubber		Ferrous metals		Electronics		Rare Earths	
	/ min	/ MAX	/ min	/ MAX	/ min	/ MAX	/ min	/ MAX
2025								
Mass - kg	1,123	1,457	7,833	9,574	5,909	7,223	2,004	2,450
Value - EUR	262	339	1,817	2,221				
2030								
Mass - kg	2,821	3,655	19,890	24,310	14,833	18,129	5,226	6,387
Value - EUR	657	852	4,615	5,640				
2035								
Mass - kg	137,512	173,779	293,091	358,222	258,712	316,204	76,416	93,397
Value - EUR	32,040	40,490	67,997	83,108				
2040								
Mass - kg	636,632	798,448	1,177,359	1,438,994	892,513	1,090,849	307,280	375,565
Value - EUR	148,335	186,038	273,147	333,847				
Total Mass - kg	**778,087**	**977,339**	**1,498,173**	**1,831,101**	**1,171,968**	**1,432,405**	**390,927**	**477,799**

Table 26: Projections of material recovery associated with specific components - Green Constraint scenario (mass in kg)

Note: the two estimates of material recovery—by simple pre-sorting OR by detailed material composition—are based on different approaches for the same perimeter and are therefore, in principle, NOT complementary; the resulting economic elements cannot therefore be added together.

8. Appendix D: Details of investments per year

Year	Proportion of ELV centers with trained staff with basic training	Proportion of ELV centers with staff with advanced training	Investment basic training period (EUR)	Investment in advanced training (EUR)	Investment in basic training - discounted (EUR)	Investment in advanced training - updated (EUR)
2022	60%	10%	102,000	170,000	102,000	170,000
2023	60%	10%	-	-	-	-
2024	60%	10%	102,000	170,000	92,517	154,195
2025	60%	10%	-	-	-	-
2026	60%	20%	102,000	340,000	83,916	279,719
2027	70%	20%	-	-	-	-
2028	70%	20%	119,000	340,000	88,800	253,713
2029	70%	20%	-	-	-	-
2030	70%	30%	119,000	510,000	80,544	345,188
2031	70%	30%	-	-	-	-
2032	80%	30%	136,000	510,000	83,492	313,096
2033	80%	30%	-	-	-	-
2034	80%	40%	136,000	680,000	75,730	378,649
2035	80%	40%	-	-	-	-
2036	80%	40%	136,000	680,000	68,689	343,446
2037	90%	40%	-	-	-	-
2038	90%	50%	153,000	850,000	70,091	389,395
2039	90%	50%	-	-	-	-
2040	90%	50%	153,000	850,000	63,575	353,193
Total			1,258,000	5,100,000	809,353	2,980,594

Table 27: Annual investment in training as a function of the growth in the number of ELV centers with trained staff

Year	Proportion of ELV centers with a bridge	Proportion of ELV centers with a table	Investment period - bridge (EUR)	Investment period - table (EUR)	Investment bridge period - discounted (EUR)	Investment table period - discounted (EUR)
2022	50%	20%	-	-	-	-
2023	50%	20%	-	-	-	-
2024	50%	20%	-	-	-	-
2025	50%	30%	-	1,020,000	-	881,114.35
2026	50%	30%	-	-	-	-
2027	50%	30%	-	-	-	-
2028	50%	40%	8,500,000	3,060,000	6,342,831	2,283,419.11
2029	50%	40%	-	-	-	-
2030	50%	40%	-	-	-	-
2031	50%	50%	-	1,020,000	-	657,501.09
2032	50%	50%	-	-	-	-
2033	50%	50%	-	-	-	-
2034	50%	50%	-	-	-	-
2035	50%	50%	-	-	-	-
2036	50%	50%	-	-	-	-
2037	50%	50%	-	-	-	-
2038	50%	50%	-	-	-	-
2039	50%	50%	-	-	-	-
2040	50%	50%	-	-	-	-
Total			8,500,000	5,100,000	6,342,831	3,822,034.56

Table 28: Annual investment in equipment as a function of the increase in the number of ELV centers equipped

Year	Proportion of UHVCs with diagnostic capability	Investment period - equipment (EUR)	Investment period - diagnostic training (EUR)	Investment period - equipment - discounted (EUR)	Investment period - diagnostic training - updated (EUR)
2022	0%	-	-	-	-
2023	0%	-	-	-	-
2024	0%	-	-	-	-
2025	20%	1,020,000	340,000	881,114	293,705
2026	20%	-	-	-	-
2027	20%	-	340,000	-	266,399
2028	20%	-	-	-	-
2029	20%	-	340,000	-	241,632
2030	40%	1,020,000	-	690,376	-
2031	40%	-	680,000	-	438,334
2032	40%	-	-	-	-
2033	40%	-	680,000	-	397,582
2034	40%	-	-	-	-
2035	70%	2,040,000	1,020,000	1,081,856	540,928
2036	70%	-	-	-	-
2037	70%	-	1,020,000	-	490,637
2038	70%	-	-	-	-
2039	70%	-	1,020,000	-	445,023
2040	70%	-	-	-	-
Total		4,590,000	5,950,000	2,923,810	3,360,337

Table 29: Annual investment in diagnostic capacity as a function of the number of ELV centers equipped

ABOUT ADEME

Here at ADEME - The French Agency for Ecological Transition - we are firmly committed to fighting global warming and the depletion of our natural resources. On all fronts, we mobilise citizens, economic actors and territories towards a fairer, more harmonious, low carbon and resource-efficient society. Whatever the field - energy, circular economy, food, mobility, air quality, adaptation to climate change, soils, etc. - we advise, facilitate and help finance many projects, from research to solutions sharing. At every level, our expertise and forecasting capacities serve to guide and inform public policies.

ADEME is a public agency under the joint authority of the Ministry for an Ecological Transition and the Ministry for Higher Education, Research and Innovation.

ADEME'S COLLECTIONS



FACTS AND FIGURES
ADEME is a reference – ADEME provides objective analyses based on regularly updated quantitative indicators.



KEYS TO ACTION
ADEME is a facilitator – ADEME compiles practical handbooks and guidelines to help actors implement their projects methodically and in compliance with regulations.



FOCUS ON ACTION
ADEME is a catalyst – Actors and stakeholders talk about their experience and share their know-how.



EXPERTISE
ADEME is an expert – ADEME reports on research, studies and collective work carried out under its supervision.



HORIZONS
ADEME looks to the future – ADEME promotes a forward-looking and realistic view of the energy and environment transition and what is at stake for society, to build a desirable future together.

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EXPERTISES

IMPACT OF THE ELECTRIFICATION OF THE CAR FLEET ON THE ELV SECTOR

The EU and France have made it a priority to reduce transport emissions by 90% by 2050 by electrifying vehicles, provided that electricity production is decarbonized and the management of electrified ELVs is sustainable. Sales of electric and hybrid cars are increasing in Europe thanks to government policies and consumer demand. ELV centers are preparing for the arrival of these new types of vehicles.

The results of the study show that the electrification of cars will have an economic impact on the ELV sector, with an increase in the resale of second-hand parts and a burgeoning activity in the resale of mobility batteries. It is also estimated that there will be significant recycling of materials specifically related to electrification. However, the management of electrified ELVs requires appropriate equipment and training for battery removal. Investment costs of EUR 20.5 million are needed to adapt to the new processing stages.

The study takes stock of the state of readiness of the ELV processing sector in France for the transition of the vehicle fleet to electric vehicles. It highlights the expected volumes of electric and hybrid ELVs over the next 5, 10, 15 and 20 years, and includes an in-depth analysis of the technical, organizational, and economic consequences of this transition on the ELV sector.