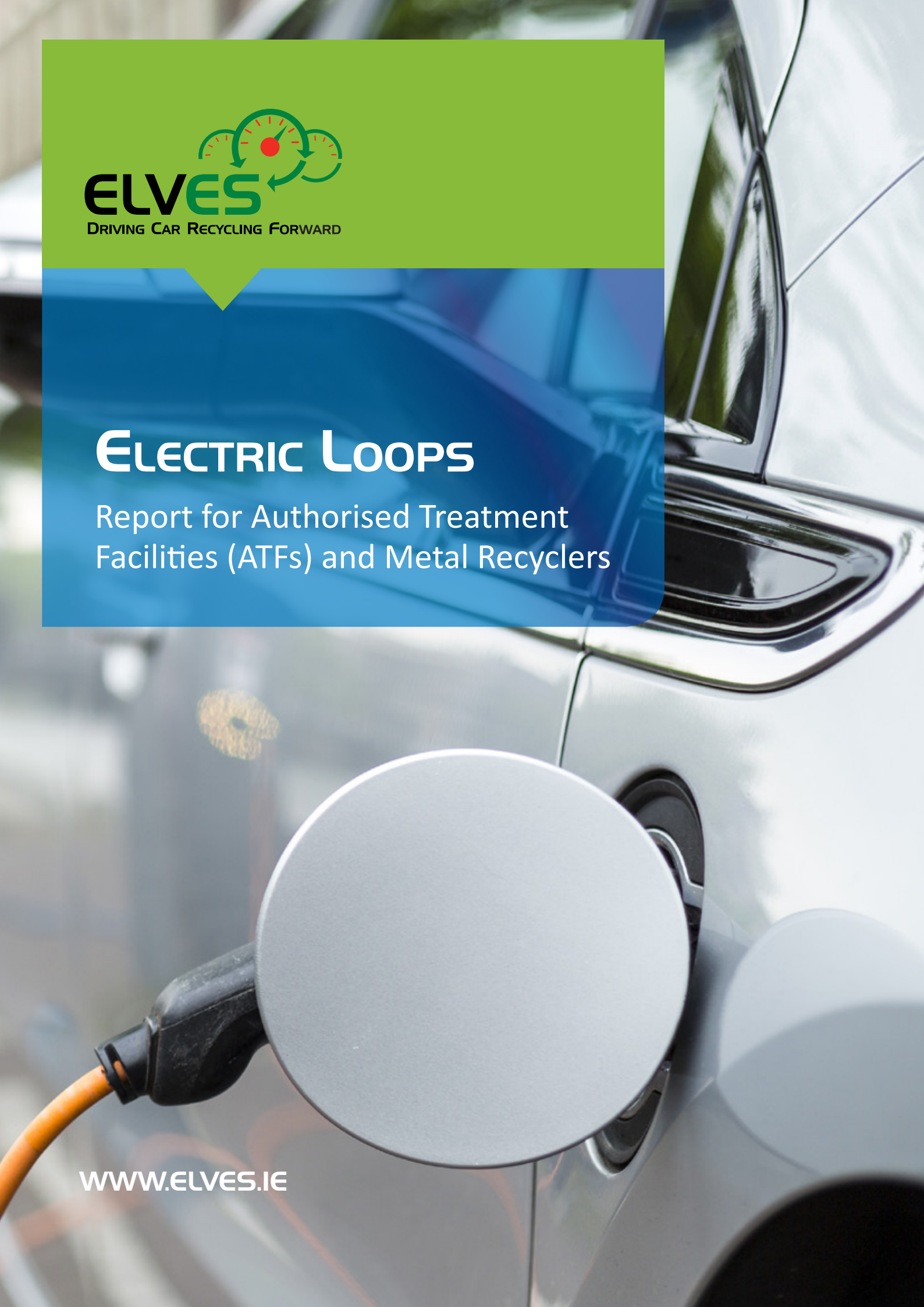
ELVES

DRIVING CAR RECYCLING FORWARD

ELECTRIC LOOPS

Report for Authorised Treatment Facilities (ATFs) and Metal Recyclers



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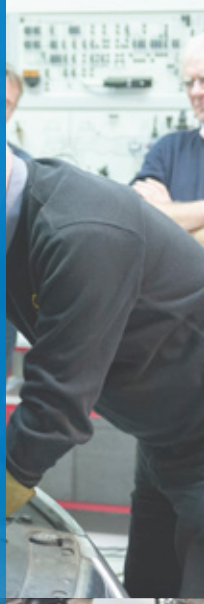





Glossary

ATF:	Authorised Treatment Facility
ELV:	End-of-Life Vehicle
EV:	Electric Vehicles (BEV, HEV and PHEV)
BEV:	Battery Electric Vehicle (full electric)
HEV:	Hybrid Electric Vehicle (hybrid no external charging)
PHEV:	Plug in Hybrid Vehicle (hybrid with external charging)
ICE:	Internal Combustion Engine Vehicle
IDIS:	International Dismantling Information System (www.IDIS2.com)

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Executive Summary

In 2023, the Electric ELVES project set out to investigate the reuse and recycling value of electric vehicles for ATFs and metal recyclers in Ireland. The project involved the dismantling, sale and evaluation of electric vehicle (EV) specific parts from two electric vehicles of different marques, alongside desk research and consultation with ATFs, metal and electronics recyclers, remanufacturers and vehicle manufacturers.

The project resulted in a Data Matrix of parts reuse and parts recycling values aimed at ATFs and metal recyclers, as well as this report. The report is designed to provide supporting information for ATFs on EV depollution, reuse and recycling as well as an outline of the key waste Regulations that have and will cover this area.

Also outlined for ATFs in this report are the safety requirements they need to be aware of, as well as the information and training available to them to ensure the safe handling of these vehicles.

Delivery on the Project Objectives

The objective of the Electric Loops project was to investigate and understand the electric vehicle (EV) value chain from the perspective of Authorised Treatment Facilities (ATFs) and recyclers, the parties that have the ability to create the circular material flows of the future.

The project had three key objectives, to:

1. Create a dataset that will aid the activities of ATFs in the reuse and recycling of electric ELVs.
2. Disseminate data from the project widely to ATFs and Metal Recyclers.
3. Create a dataset that will aid the activities of the Environmental Protection Agency (EPA), Department of the Environment, Climate and Communications (DECC) and ELVES in meeting the future requirements of the End-of-Life Vehicles (ELV) and Batteries Regulations.

This ATF Report is a supporting part of the delivery of Objectives 1 and 2. It provides additional information for ATFs on the treatment and recycling of electric vehicles and should be read in conjunction with the ATF Data Matrix.

Objective 1: Create a dataset (matrix) that will aid the activities of ATFs in the reuse and recycling of electric ELVs.

The key deliverable from the Electric Loops project was the creation of the ATF Data Matrix. This is provided as an Appendix to this report but has also been published separately.

With a focus on full electric vehicles (BEVs), the ATF Data Matrix identifies:

- What specific parts are found in EVs compared to diesel/petrol vehicles.
- What is the potential reuse value of these EV specific parts.
- What is the potential reuse demand for these parts.
- Where particular parts may have a remanufacturing value.
- What value these parts would have if removed and sold as a separate recycling stream.

The matrix was created following extensive consultation with ATFs, metal and electronics recyclers and vehicle manufacturer representatives. This was in addition to desk research and gathering data from the dismantling of the two vehicles in the project.

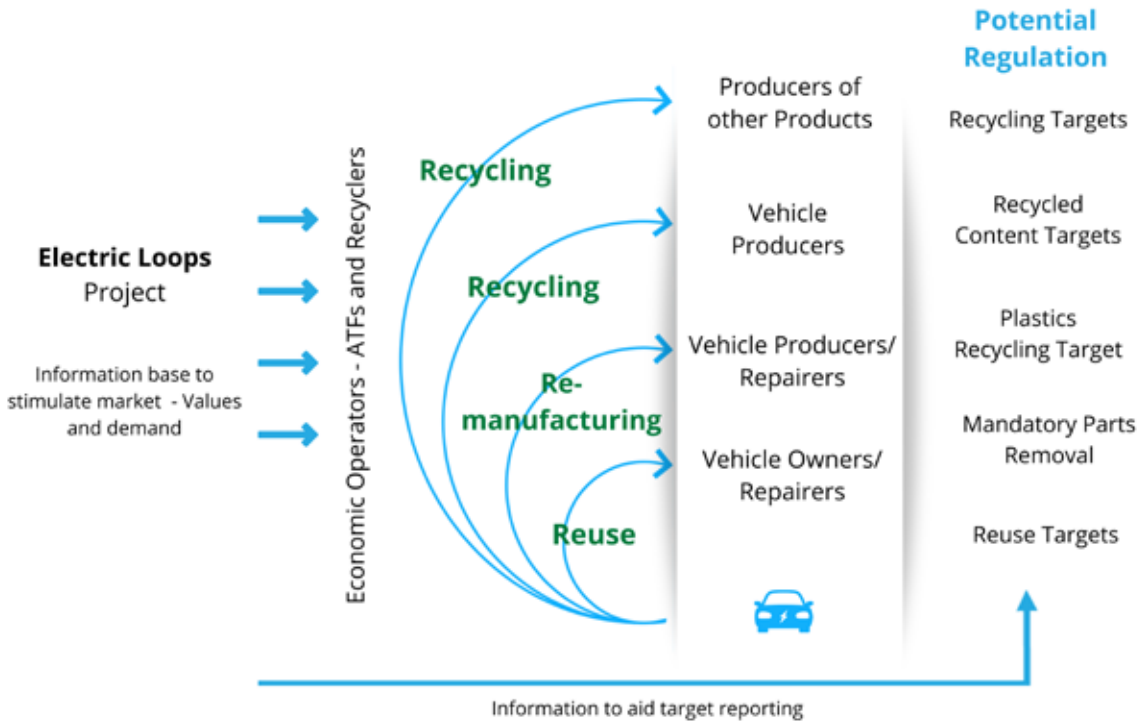
Objective 2: Data from the project is disseminated widely to ATFs and Metal Recyclers.

The ATF Data Matrix and this accompanying report is the start of the dissemination of the project results. This will continue over the coming months and will include:

- Publishing of the report on www.elves.ie accompanied by a press release.
- An in-person meeting and presentation of results to ATFs, recyclers and stakeholders.
- Issuing of the matrix and report by email to ATFs in the ELVES Network.
- Presentation of the project and results at relevant national and international events.

Objective 3: Create a dataset that will aid the activities of the EPA, DECC and ELVES in meeting the future requirements of the ELV and Batteries Regulations.

To keep information from the project as targeted and relevant as possible to its intended audience, a separate policy makers report and extended data set is being created. This will be issued at the end of the project following initial dissemination of project results, to ensure it captures all relevant data from the project.



How the Project was Carried Out

The project started with the creation of a list of the specific car parts that would be found in EV vehicles. This included identifying completely new parts (e.g. inverters) and those that were significantly different in an EV compared to an ICE vehicle.

In early June 2023, two BEVs, a Renault Zoe and a Nissan Leaf, were depolluted and their EV specific parts were removed. The parts and the vehicle were then listed on eBay and Donedeal to advertise them for sale for reuse. In addition, the parts were assessed by recyclers to ascertain a likely recycling value if that part were to arise in volume as a separate recycling stream.

The data collected was turned into a matrix of results that were reviewed by focus groups of ATFs, recyclers and vehicles manufacturer representatives before publication. Further information on how the project was undertaken can be found in Appendix B.

Information for ATFs and Metal Recyclers on the Treatment of Electric ELVs

ATF Reuse and Recycling Data Matrix

The core results of the Electric Loops project are presented in the ATF Data Matrix. The ATF Data Matrix can be found as an appendix to this report and can also be downloaded from www.elves.ie/electricloops

Depollution of Electric Vehicles

Where to Find Information

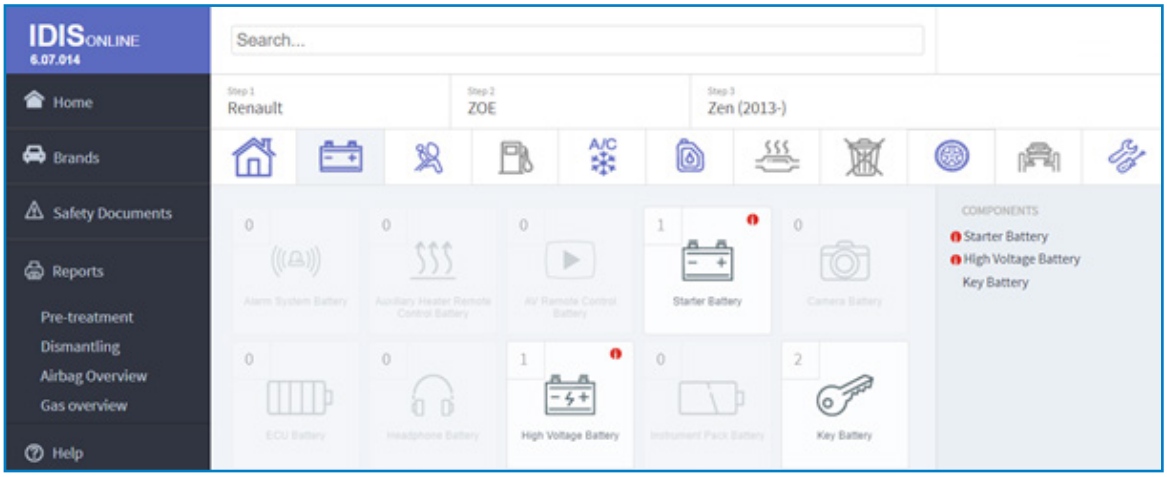
Before work commenced on either vehicle, a review of the documents available on the International Dismantling Information System (IDIS) was completed. IDIS is free for ATFs to access and contains information on every new marque and model of vehicle placed on the European market.

Key information available on IDIS for EVs

Common Information on the handing processes applicable to any manufacturer of high voltage electrical components. Includes common information on EV identification and inspection, and battery handling, transport and storage. This is found under High Voltage Battery for the specific marque/model, see image below.

Manufacturer Specific Removal Information in relation to shutting down the vehicle and removing its high voltage battery. This is found under High Voltage Battery for the specific marque/model.

Pre-Treatment Report that outlines the materials that should be removed from the vehicle during depollution. Found under Reports – Pre-treatment on left hand side of screen for the specific marque/model.



Screenshot from the IDIS System

Equipment

Steps Taken and Equipment Used During the Project

Vehicle Preparation: Before work started, a cordon was placed round each vehicle, high voltage signs placed on the vehicles and both keys removed and placed a safe distance from the vehicle using lock out tags. A high voltage safety hook was placed near the vehicle and all parties were made aware of where it was located. A battery spillage kit was also to hand.

Personal Protective Equipment (PPE): Each dismantling technician was supplied with dielectric boots, linesman's gloves and over gloves, and an Arc flash face protector with helmet. These were worn until the vehicle was shut down, the battery removed and time had elapsed to let any remaining energy dissipate from the high voltage specific parts.

Dismantling and Battery Removal Tools: During removal of the battery, insulated tools were used, along with a multimeter to test voltage. A battery table was moved under the vehicle to take the battery upon removal. Due to the weight of the battery, a pallet was placed securely on top of the battery table before the battery was placed onto it to enable easy moving of the battery with a forklift.

Key Electric Vehicle Handling Equipment:

- Rubber/Linesman's Gloves (Class 0)
- Face protection with electric arc protection
- Dielectric boots or rubber matting
- Insulated tools
- Vehicle isolation signage
- Safety hook
- Multimeter (cat 111) or Volt Detector (including proving unit)
- EV battery spillage kit
- Battery table (rated to more than the weight of the battery)
- Pallet

Training

Before commencing the dismantling, both ELV technicians completed Electric Vehicle dismantling training through the Electric ELVES programme. The training is provided free to all ATFs at various locations around the country.

Further information on training can be found on the Electric ELVES website: www.electricelves.ie

Depollution differences BEV to ICE		
Yes, present in BEV		**No, not present in BEV**
High Voltage Battery Lead Acid Battery (majority) Brake Fluid Gear Oil Gearbox Oil Filter (some marques)	Tyres Power Steering Oil Shock Absorber Oil Coolant/Antifreeze Screen Wash AC Gases Air bags	Diesel or Petrol Engine Oil Catalytic Converters Diesel Particular Filters
Check IDIS for details – www.IDIS2.com BEVs may have more than one cooling system that needs to be drained. Oils may be used in the electric motor for cooling and lubrication		

How Depolluting an EV is Different to an ICE ELV

A key difference in depolluting an EV is the need to remove the high voltage battery. This should be done first, before other depollution steps, to remove any high voltage risk in the vehicle. The battery should be removed by trained technicians, with appropriate equipment and PPE, following a review of manufacturer guidance on the shutdown and battery removal procedure for that specific vehicle.

Coolant, gearbox oil, brake fluid, shock absorber oil and wash fluid will all still be present in a EV and should be removed during depollution. AC Gas (Refrigerant) will also need to be removed during depollution.

Some BEV, HEV or PHEV vehicles have two (or three) cooling systems - one for the engine, one for the inverter, and possibly another for the battery. All of these must be drained during depollution.

BEVs do not have fuel to remove, engine oil or engine oil filters. However, these will be present in HEV and PHEV vehicles.

IDIS can be used to check what depollution liquids are present and need to be removed. The record for each vehicle should include a Pre-Treatment Report.

Depollution Results from the Electric Loops Study

Depollution of the two vehicles was done following a review of the vehicle depollution documents from IDIS. The results from the depollution were as follows.

Renault Zoe				
	Present?	Weight in new vehicle (from IDIS)	Weight found in vehicle	Comments
Battery – Starter	✓	11.22kg	12.9kg	
Battery - Key	✓	3g	N/A	
Battery - BEV	✓	290kg	N/A	Not weighed during study – too heavy
Coolant	✓	3.79kg	2.965kg	
Gear Box Oil	✓	0.46kg	0.45kg	
Brake Fluid	✓	0.6kg	0.67kg	
Shock Absorber Oil	✓	90g	N/A	Shock Absorber Oil - Not removed due to reuse potential. Listed on IDIS as Damper Oil/Suspension Fluid
Wash Fluid	✓	2.16	0.225kg	
Engine Oil	✗	N/A	N/A	
AC Gas – R1234yf	✓	0.990kg	0.467kg	

Nissan Leaf				
Battery - Starter	✓	12kg	N/A	Already removed from vehicle
Battery – Key	✓	2g	N/A	
Battery – BEV battery	✓	292.1kg	N/A	Not weighed during study – too heavy
Coolant	✓	7.768kg	5.62kg	Estimate*
Gear Box Oil	✓	0.962kg	1.005kg	Gear Box Oil - Included small amount of coolant. Listed in IDIS as Clutch Fluid.
Brake Fluid	✓	0.613kg	0.255kg	
Shock Absorber Oil	✓	0.469kg	N/A	Not removed due to reuse potential. Listed on IDIS as Damper Oil/ Oil.
Wash Fluid	✓	2.5kg	0.49	
Engine Oil	✗	N/A	N/A	
AC Gas - R134a	✓	0.450kg	0kg	Tested but none found

*Vehicle was depolluted and coolant removed. However, coolant lines ran the length of the vehicle, meaning additional coolant was unexpectedly found during dismantling which was not captured – 1kg of the estimated 5.65Kgs.

Parts Removal

What New Parts can be Found in Electric Vehicles?

Through the project a list of BEV specific parts was created with information gathered on part location where possible. Based on consultation with a range of vehicle manufacturers, the key BEV specific parts were identified as follows:

BEV Specific Parts, many also found in HEVs and PHEVs

Electric Motor(s)
Reducer/Gearbox
High Voltage Battery

Inverters, commonly:

- Motor Inverter (DC (Battery) to AC (motor))
- Onboard Charger* (AC (charging input) to DC (battery))

Converters, commonly:

- DC DC Converter

High Voltage Air Conditioning (AC) Compressor
High Voltage PTC (Positive Temperature Coefficient) Heaters
EV Specific Control Modules
Vehicle Sound Pedestrian (VSP) Speaker & Control Module
High Voltage Cables (orange cabling)
Charging Socket & Flap*
External Charging Cable*
HV Battery Fan (for some air-cooled batteries)

*would not be found in a HEV as no external charging

As identified in the matrix, parts were categorised based on whether they were:

- **O:** Only found in BEVs, HEVs or PHEVs
- **D:** Different in a BEV to an ICE vehicle
- **M:** Maybe Different in a BEV to an ICE vehicle (depends on marque/model)
- **S:** Is the Same in an ICE compared to a BEV

Parts in categories O, D and M were considered BEV related for the purposes of this report.

Learnings from Parts Removal

It is vitally important that the vehicle is made safe and any high voltage risk is removed from the vehicle before parts are removed. This was done through the removal of the high voltage battery and waiting a short time for any remaining energy in the high voltage parts to dissipate.

Where possible, prior to dismantling, information was gathered on the location of the BEV specific parts. The location was not the same in each vehicle – for both vehicles the charging socket was at the front of the vehicle. However the onboard charger was in the rear of the Nissan, whereas for the Renault its equivalent was at the front of the vehicle. Finding some of the parts, especially smaller ones, was a challenge.

During the study the motor block was lowered from the vehicle to enable easy access to the parts.

The varying location of parts, and this being the first time dismantling them, meant it was not possible to accurately record the time taken to dismantle the parts during the study.

It was found in dismantling that the high voltage orange plug connections could be brittle and have clasps that need to be released before removal. As such, care should be taken on removal to ensure they are intact for part reuse.

Reuse, Remanufacturing and Recycling of BEV Parts

Reuse

After 9 months of being listed for sale, a total of 29 parts had been sold from the two vehicles, of which 13 were BEV related - only found in BEVs, different in a BEV to an ICE vehicle or may be different in a BEV than an ICE.

The fastest part to sell was the PTC Heater from the Nissan Leaf which sold in one day. Total BEV related part sales value was >€5,500, >€1,400 for the Leaf and >€4,100 for the Zoe[1]. The destination countries of the 13 BEV related parts were split between Ireland (5) and the UK (7), with one part sold to Spain. Prices include postage where applicable. Non-BEV specific part sales totalled >€2,300.

Some parts that did not sell during the sales period analysed are still considered 'likely to sell' by the ATF Focus Group based on their experience. These additional parts include the Brake Master Cylinder and Axle.

Parts sold from Renault Zoe	Parts sold from Nissan Leaf
BEV related: • Battery • Charger Flap • Charging Socket • High Voltage Cable • PTC Heater[2] • AC Compressor • Heating Resistor[2] • Subframe Part • Charger Assembly **Non-EV related:** • AC Accumulator Assembly Dryer • Bumper • Doors x 2 • Window Switch • Window Regulator • Wheels • Front Panel	**BEV related:** • Onboard Charger • Charging Cable • PTC Heater • Traction Motor Inverter **Non-EV related:** • Electric Parking Brake Control Module • Electric Water Pump • Doors x2 • Window Switch • Front Shocks x2 • Front Hubs x 2 • Door Cards x 4 • Rear Bumper • Radiator Pack
Total Value: >€5,400	**Total Value: >€2,500**

[1]*Some parts were not suitable for reuse and as such not listed for sale. This included the Battery and the DC DC Converter from the Nissan Leaf and the Electric Motor from the Renault Zoe. This would have affected the potential total sales value from each vehicle.*

[2]*Potentially different in a BEV to an ICE vehicle, although not in a Renault Zoe.*

Remanufacturing

General feedback from part remanufacturers was that it was very early days for parts remanufacturing, and volume needs to increase before markets can develop. Opportunities to remanufacture batteries already exist, along with remanufacturing of parts similar to their ICE equivalent (e.g. high voltage AC Compressors). Feedback suggested remanufacturing opportunities will develop for high value parts where easy disassembly for cleaning and checking is possible.

Recycling

Best estimates on recycling values were provided by metal recyclers and electronics recyclers to inform the figures in the matrix. However, it is noted that volume is needed before accurate assessment can be done on the material value of these parts at scale. For example, analysis of high voltage cable from the project suggested 17% copper content, putting it at the lower grade of copper cabling. A recycler said further analysis on a larger sample was needed to see if this would be the case across marques and cables. Increases in volume will also support the development of specific recycling avenues for certain parts. For example, specialist recyclers focusing on the recovery of specific materials like rare earth magnets. It is also expected that this will be supported by Regulation specifying removal of certain parts, and their separate treatment.

Regulations Around EV Dismantling

The Regulations covering the depollution, dismantling and recycling of EVs are changing.

As ATFs are already aware, the depollution and dismantling of electric ELVs has fallen under the following two key Directives, implemented through Irish Regulation:

1. Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles, implemented as
    - S.I. No. 281/2014 - European Union (End-of-Life Vehicles) Regulations 2014
2. Directive 2006/66/EC of the European Parliament and of the Council of 6 September 2006 on batteries and accumulators and waste batteries and accumulators and repealing Directive 91/157/EEC, implemented as
    - S.I. No. 283/2014 - European Union (Batteries and Accumulators) Regulations 2014

These two Regulations have applied to EVs and other vehicles. In particular, the ELV Regulation specifies that batteries should be removed during depollution.

The 2014 Batteries Regulation ensures the free collection and recycling of those batteries is provided for by producers. As with ICE vehicles, parts from EVs and their recycling contribute to the achievement of the reuse and recycling targets under the ELV Regulations.

Free collection and recycling of EV batteries is currently provided through the Electric ELVES programme. All ATFs can request a free EV battery collection through the Electric ELVES website, as well as access additional resources and sign up to electric vehicle handling training - www.electricelves.ie.

Over the last few years, both these Directives have undergone reviews with new Regulations proposed, and in the case of Batteries, a Regulation has been passed and adopted.

The ELV (End-of-Life Vehicle) Directive under Review

A Proposal for a Regulation on circularity requirements for vehicle design and on management of End-of-Life Vehicles was published on the 13th of July 2023. The proposal is designed to replace the current ELV Directive as well as Directive 2005/64/EC on the type-approval of motor vehicles with regard to their reusability, recyclability and recoverability ("3R type-approval Directive", adopted in 2005).

The new ELV Regulation is currently being negotiated, but based on the initial proposal and of relevance to this project, it has the potential to:

- Introduce a plastics specific recycling target.
- Introduce a Circular Vehicle Passport that should provide additional information to ATFs and recyclers on part location and removal, and vehicle recyclability.
- Introduce a mandatory list of parts that should be removed at ATFs prior to vehicle shredding.
- Introduce labelling and warranty requirements for second hand parts. It states that parts assessed as fit for reuse, remanufacturing or refurbishment shall not be considered waste

The potential mandatory list of parts for removal is of relevance to this project and ATFs. The proposal states that alongside parts found in both EVs and ICE vehicles, EV Batteries and E-drive motors will be required to be removed at the ATF level for reuse or separate recycling. Inverters and parts with a printed circuit board larger than $10cm^2$ will also be subject to this requirement, unless it can be proven their materials can be separated as efficiently post shredder. The list of parts in the initial proposal can be seen in Appendix D.

The proposal is still under negotiation, but once agreed may well affect the options available to ATFs in the reuse and recycling of EV vehicles.

The New Batteries Regulation - Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC

The new Batteries Regulation entered into force on the 17th August 2023, with initial provisions applying from the 18th February 2024. Once removed from an ELV, EV Batteries fall under the Batteries Regulation rather than the ELV Regulation in terms of how they are managed and the recycling targets that have to be met.

The Regulation:

- Introduces a new battery type, that of electric vehicle battery.
- Sets recycling efficiency targets for li-ion (lithium ion) batteries.
- Introduces a framework for the reuse and repurposing of EV batteries. Repurposed EV batteries will be considered new products, with the operator that places the 'new' battery on the market considered its Producer with Extended Producer Responsibility (EPR) obligations.
- Introduces more extensive EPR for EV batteries from 2025. Producers will continue to provide free collection and recycling of EV batteries.

ATFs removing EV batteries from ELVs will need to be familiar with these Regulations and the obligations they place on them.

Electric Loops - Reuse, Remanufacturing and Recycling of Electric Vehicles

Electric Vehicle Part		Reuse			Remanufacturing	Recycling[4]			
	Part Name	Price sold for[1] (Days to sell)	Comparative Parts Pricing Average listing price[2]	Comparative Parts Demand No. of units no longer listed after 3 months[3]	Remanufacturing AN: Available Now F: Likely in the future	Weight (Kg) measured in study	Key factors/materials influencing value (e.g. copper content)	How material would likely be labelled for sale currently	Estimated value in todays market (€/tn)
Battery	Battery[6]	€2000 (14 days)	Av. €2,967 from 27 li-ion listings, av. €755 from 3 NiMH listings from a mix of hybrid and BEV vehicles. Est. price per kWh €110-€120 per usable kWh for second hand battery pack, e.g. a 50kWh battery pack at 80% SOH, estimate €4,400.	12 of 30 Batteries	AN: Yes NiMH, No Li-ion F: Yes, challenges remain due to low standardisation	290 273	Cobalt, Lithium, Nickel and Copper	Li-ion Battery	Negative
Electric Motor	Electric Motor & Reducer combined Externally Excited Synchronous Motors (EESM)[5]	Not listed for sale	Electric Motor: Av. €1,659 from 30 listings. Range: €288 (Kia Niro) to €6,900 (Porsche Taycan).	27 of 30 Motors	AN: No F: Yes, have potential for very long life	76.42	Copper, potentially Aluminium and Rare Earth Magnets (REMs) REMs could become a key indicator of value, although not reflected in markets yet. Ferrous (e.g. Iron) contamination has the potential to reduce value. According to JRC[6] all HEV and PHEV e-drive motors are Rare Earth Permanent Magnet motors. 23% of BEVs have Rare Earth Permanent Magnet-free motors.	Electric Motors	€400-500 1tn - approx 15 units Value likely to be less if combined with gearbox. Price could increase per tn with further dismantling and segregation of motor components.
	Electric Motor Interior Permanent Magnet Synchronous Motor[5]	NS				60.94			
	Reducer/Gearbox[5]	NS	Reducer/Gearbox/Transmission: Very few results. Av. €1,184 from 3 listings. Range: €259 (Kia Niro) to €2,559 (BMW i8).	2 of 3 Reducers	AN: No F: Yes	28.87	Aluminium and Steel Ferrous contamination has the potential to reduce value.	Irony Aluminium	€350-450 1tn - approx 35 units
Inverters (& Rectifiers) and Converters	Inverter with Converter[4]	NS	Converter/Inverter: Av. €537 from 32 listings. Range: €144 (Toyota Prius) to €2,875 (BMW i8).	17 of 32 Converter/Inverter	AN: No F: Yes	11.54	Copper, Aluminium, and Printed Circuit Boards Ferrous contamination has the potential to reduce value.	Mixed Electronic Components or potentially a high quality Aluminum classification	€400-500 1tn - approx 60 units Prices varied significantly, based on casing materials and Printed Circuit Board quantity. Highest value quoted was €1,380 per tn. One recycler suggested Charger Assembly w/Junction Box and Onboard Charger would contain more valuble elements than Inverters/Converters.
	Traction Motor Inverter[5]	€304[1] (261 days)	Inverter: Av. listing price of €412 from 10 listings. Range from: €170 (Toyota Auris) to €1,380 (Renault Kangoo).	4 of 10 Inverters	AN: No F: Yes	16.46			
	DC DC Converter	Not listed for sale	Converters: Av.€420 from 10 listings. Range: €71 (Toyota Yaris) to €1,150 (Kia Sportage).	8 of 10 Converters	AN: No F: Yes	15.21			
	Charger Assembly with Junction Box[4]	€1397 (251 days)	Onboard Chargers (OBC): Av. €540 from 10 listings. Range: €171 (MG ZS) to €885 (Mercedes Benz E Sprinter).	10 of 10 OBCs	AN: No F: Yes	26.38			
	Onboard Charger[4]	€750 (20 days)			AN: No F: Yes	16.39			
Control Modules	EV Specific Control Modules	NS	Difficult to identify EV specific control modules for sale. Examples found - BMS control unit (Jaguar IPACE) €153 and Convenience Charging Control Unit (BMW) €920.	2 of 4 Control Modules	AN: No F: Yes, software and coding will become important	0.52	Copper, Aluminium and Printed Circuit Boards	Mixed Electronic Components	€600-700 1tn - approx 1800 units
Charging System	Charging Cable	NS	Av. €116 from 20 listings. Range: €40 (generic) to €184 (Tesla).	18 of 20 Charging Cables	AN: No F: No	2.57	Copper and potentially higher value metals at connections	Copper Cable or Mixed Electronic Components	€800-900 1tn - approx 660 units Depending on copper contents: <28% - <€1000 >28% and above - €1200 >60% - up to €3000 High voltage internal cable analysed in study was 17% copper.
		€130 (73 days)				1.62			
	Charging Socket	€145[1] (37 days)	Av. €231 from 10 listings. Range: €144 (Mercedes C Class) to €362 (Porsche Taycan).	5 of 10 Charging Sockets	AN: No F: Yes	1.56			
		NS				1.005			
	High Voltage Cables	Cable 1: €60[1] (4 days)	Av. €143 from 20 listings of single Cables. Range: €18 (Skoda Citygo) to €276 (Renault Clio).	4 of 20 HV Cables	AN: No F: Yes	Cable 1: 1.37 Cable 2: 1.64 Cable 3: 0.18 Total: 3.19			
		NS				2.19			
	Charger Flap	€130 (43 days)	Av. €162 from 6 listings. Range: €299 (Hyundai Kona) to €43 (Renault Kangoo).	3 of 6 Charger Flaps	AN: No F: Uncertain	0.90	N/A	Scrap Plastic	€150-200 1tn - approx 1100 units
		NS				1.09			
Thermal Management System	AC Compressor or Heat Pump	€274[1] (35 days)	Av. €228 from 25 listings. Range: €71 (Toyota Prius) to €989 (BMW 330e).	5 of 25 AC Compressors	AN: Yes, alongside ICE versions F: Yes	6.29	Aluminium and Copper Ferrous contamination will determine the price.	Irony Aluminium, potentially Mixed Electronics Components	€300-400 1tn - approx 150 units
		NS				6.64			
	Battery Fan	NS	Av. €117 from 14 listings. Parts varied significantly in size with the Renault Zoe Fan larger than most.	7 of 14 Battery Fans	AN: No F: No	Not weighed	Plastic	Low value WEEE or Plastics	Low value - less than shell value
	Coolant Lines	NS	Few comparable listings found. Coolant Return Hose from a BMW listed at €35 - €58.	1 of 5 Coolant Lines	AN: No F: No	1.94	Low value due to weight and material content.	Low value WEEE	Low value - less than shell value
Electronics	Vehicle Sound Pedestrian (VSP) Speaker	NS	No others listed	N/A	AN: No F: No	0.545	Steel	WEEE	Up to €150, potentially negative value 1tn - approx 1200 units
	Vehicle Sound Pedestrian (VSP) Control Unit	NS	No others listed	N/A	AN: No F: No	0.27	Steel and potentially Precious Metals	WEEE	Up to €300, potentially negative value 1tn - approx 1500 units
	Display Unit Instrument Panel (Speedometer etc)[6]	NS	Av. €207 from 20 listings. Range: €57 (Nissan Leaf) to €1,087 (Jaguar IPACE).	12 of 20 Speedometers	AN: No F: Yes	0.63	Potentially Printed Circuit Boards and Critical Raw Materials Most recyclers considered it low value	WEEE or LED screen	On par with shell value 1tn - 1500 units
Brakes and Steering	ABS Booster/ABS Pump Modulator	NS	Av. €167 from 7 listings. Range: €127 (Honda Civic Hybrid) to €210 (another Honda Civic Hybrid).	3 of 7 ABS	AN: No F: Yes	3.66 1.66 (2 units)	Steel and Aluminium	Irony Aluminium	€150-250 1tn - approx 400 units
		NS				2.069			
Axle subframe	Axle/Motor Subframe	€40 (1 section sold) (17 days)	N/A	N/A	AN: No F: e-axle - yes, other parts uncertain	34.90 18.68 (2 parts weighed)	Steel	Steel	€100 -120. on par with shell prices 1tn - approx 20 units
Thermal Management System	PTC (Positive Temperature Coefficient) Heaters	€71[1] (144 days)	N/A	N/A	AN: No F: Yes	0.33	Aluminium and Copper	Irony Aluminium or potentially Mixed Electronic Components	€350 - 450 with one quote of €800 p/t 1tn - approx 600 units
		€247[1] (1 day)				3.02	Not examined		
	Heating Resistor	€50 (97 days)	N/A	N/A	AN: No F: No	0.14	Aluminium	Irony Aluminium or Dirty Aluminium	€300- 400 1tn - approx 7500 units
		NS			AN: No F: No	0.13			
Brakes & Steering	Power Steering Boxes/Steering Motor	NS	N/A	N/A	AN: No F: Yes	One unit weighed 10.8kg excl steering wheel, indicators etc.	Steel and Aluminium	Irony Aluminium	On par with shell value 1tn - approx 90 units
		NS							
	Brake Master Cylinder	NS	N/A	N/A	AN: No F: Yes	2.98	Steel and Aluminium	Irony Aluminium or Non-Ferrous	On par or below shell value 1tn - approx 330 units
	Brake Pads	Not listed for sale			AN: No F: No	1.05	Steel	Steel	On par with shell value 1tn - approx 950 units
	Brake Shoes	Not listed for sale			AN: No F: No	1.93	Steel	Steel	On par with shell value 1tn - approx 520 units
	Brake Callipers	NS	N/A	N/A	AN: Yes F: Yes (not considered EV specific)	5.81	Steel	Steel	On par with shell value 1tn - approx 170 units

Parts Colour Key:

- Only found in BEVs, HEVs or PHEVs
- Different in a BEV than an ICE vehicle
- May be different in a BEV to an ICE vehicle (depends on marque/model)

1. Where parts were bought in GBP (Price sold for) or Listed (Comparative Parts Pricing) a conversion rate of 1.15 was applied to provide Euro value (avg. of previous 12 months). Prices include postage and are rounded to the nearest €. NS: Not sold during study period.
2. Price data taken from eBay listings on a range of used parts from hybrid and electric vehicles. Postage excluded where possible.
3. Data taken from eBay listings on a range of EV parts that were no longer listed 3 months after initial sample was taken. Initial listing date unknown.
4. ELV Shell Prices: For comparison to the estimated prices provided for segregated parts, recyclers have provided ELV shell price estimates in the range of €115-150 per tn (December 2023). Part value estimates based on LME, European and Asian markets.
5. Listed as one of the 19 parts that should be removed before shredding in the Proposal for a Regulation on circularity requirements for vehicle design and on management of End-of-Life Vehicles. See ATF report for more detail.
6. JRC Report - N. Tazi, M. Orefice, C. Marmy, Y. Baron, M. Ljunggren, P. Wäger, F. Mathieux, May 2023, JRC SCIENCE FOR POLICY REPORT, Initial analysis of selected measures to improve the circularity of critical raw materials and other materials in passenger cars.

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Appendix B: How the Research was Carried Out

Developing the Parts List

The first stage of the project was to research the key parts of an electric vehicle. This was done though a mixture of desk-based research and feedback from project stakeholders including vehicle manufacturer representatives, ATFs, metals recyclers, the EPA and DECC.

A car parts list was created, based on BEV related parts identified and the existing car parts list used for the reporting of reuse data for ELV target achievement. List creation focused on BEV specific parts, although many parts would also be found in HEVs and PHEVs. The list was then provided to the stakeholder group requesting feedback on the classification of parts and on the potential metrics to be measured. The stakeholders were asked to add any BEV parts we had not yet identified.

The parts list was categorised based on whether the parts were:

- O: Only found in BEVs, HEVs or PHEVs
- D: Different in a BEV to an ICE vehicle
- M: Maybe different in a BEV to an ICE vehicle (depends on marque/model)
- S: Is the Same in an ICE compared to a BEV
- I: Only found in an ICE vehicle and not in a BEV.

The dismantling initially focused on the parts identified as O or D. Further refinement using manufacturer input resulted in the use of another category: M - Maybe different in a BEV to an ICE vehicle (depends on marque/model). This was relevant to parts like PTC heaters that in the majority of EVs are high voltage but in some marques are powered by the 12v battery and would therefore be the same in ICE vehicles.

Once the BEVs had been chosen for dismantling, further extensive feedback on the parts list was gained from representatives of Nissan Ireland and Renault Ireland in relation to the cars being dismantled.

Sourcing an Electric Vehicle and an ATF to undertake the dismantling.

In parallel to parts list development, communications were sent out to the ELVES ATF Network seeking expressions of interest to be the host ATF for the dismantling. An ATF that specialises in parts reuse was chosen from those that responded, with other ATFs also being given the opportunity to participate in the project by being part of the ATF Focus group. A fortnight before the dismantling, two staff from the host ATF were able to attend Electric Vehicle dismantling training through the Electric ELVES programme. Both technicians also familiarised themselves with the relevant vehicle dismantling documents available on IDIS.

A review of popular BEV marques and models was undertaken using data from Motorstats.ie as well as a review of potential second hand BEVs that were available for sale within the project budget. Communications were sent out to vehicle manufacturer contacts; in case any were able to assist in the sourcing of a BEV for dismantling.

Following the research, it was decided to purchase a 2015 Renault Zoe for dismantling. In response to our communication to our ATF Network, the project was also offered a 2012 Nissan Leaf for dismantling under the project. This enabled us to dismantle the BEV specific parts from two electric vehicles, rather than the originally intended one. This was undertaken within budget, with significant benefit to the resulting dataset.

Dismantling the vehicles

The dismantling of the two vehicles occurred over three consecutive days in June 2023 at Autotowing Ltd, Limerick. Two ATF staff were on hand, initially working together to shut down the vehicle and remove the batteries, and then to complete the rest of the depollution and remove the parts identified in our parts list.

ELVES staff photographed the removed parts and weighed them. Weights were also taken of the depollution materials as they were removed from the vehicles.

Recording of reuse, recycling and remanufacturing metrics.

Once the parts were removed from the vehicles, they were listed for sale on the Autotowing website and on eBay. The vehicles for 'breaking' were also listed on Donedeal and an ad placed in the Recycled Parts section of Autobiz magazine. A representative of eBay advised the project team on how best to advertise the parts (for example the importance of using a white background) and how to retrieve sales data from their system.

Initially recyclers were asked for their input and provided with photographs, weights and measurements for the parts removed. However, feedback from them suggested more information on material content was really needed for them to make more accurate assessments of value. To aid recycling assessment two activities were undertaken. Firstly, two of the BEV parts that had been damaged on removal (a motor and an inverter) were disassembled, the materials were assessed and weighed, including sending some samples to the UK for assessment. Secondly for parts destined for reuse, these were assessed by staff from Oran Metal recycling using an XRF gun. The data from these assessments and any additional information from desk research was added to the reuse and recycling matrix and provided to recyclers for value assessment.

To assess remanufacturing opportunities a survey was created for companies currently involved in remanufacturing. This asked information on where they operated (for example do they source from Ireland) whether they currently remanufacture any of the BEV specific parts identified or whether they think there may be an opportunity to do so in the future. Vehicle manufacturers and ATFs were also asked as part of the second round of consultation if they knew of any remanufacturing opportunities for these parts.

Creation of the Matrix

The creation of the matrix was a multi-step process. Consultation was undertaken with ATFs, metal recyclers and vehicle manufacturers on its format to ensure its usefulness and to sense check its accuracy once data was added. Data for the matrix came from multiple sources including the dismantling of the vehicles, analysis of reuse sales, remanufacturing surveys and detailed analysis by recyclers.

Appendix C: Electric Vehicle Specific Parts - Further Information on Function and Presentation

EV Battery

The EV Battery may be air cooled or use coolant. The Battery Management System maybe in the battery pack or external. Likely to contain one or more control modules.

Electric Motor

The Electric Motor in an EV takes the place of the engine. There may be up to four per vehicle, for example one on each axle, or one per wheel. According to the Joint Research Centre, all HEV and PHEV e-drive motors are Rare Earth Permanent Magnet (REPM) Motors. For BEVs, 77% use REPM Motors, the rest use REPM Free motors. The magnets in motors can affect the operation of electrical devices including pacemakers, mobile phones, smart watches etc.

Reducer/Gearbox

The Reducer in an EV takes the place of a gearbox or transmission in an ICE vehicle; it may be separate to the motor or combined as one part. A Reducer is similar to a gearbox but would normally only have one speed/gear. It would normally include the differential.

Converter

A Converter changes voltage up or down. For example, the DC DC Converter (also known as Auxiliary Power Module) converts DC from the battery pack to lower voltage for use in lower voltage applications (e.g. lights, power steering).

Inverter

An Inverter changes AC to DC or DC to AC. AC to DC Inverters are also known as Rectifiers.

An example would be the Onboard Charger (OBC). The OBC converts AC power from external sources, such as residential outlets, to DC power to charge the vehicle battery pack. The OBC is not used for DC Charging (high speed charging) and would not be found in a hybrid (as no external charging).

A Traction Motor Inverter would change DC power from the battery to AC power for the electric motor.

Junction Box - many EVs have a part called the Junction Box, this is an enclosed unit that houses and protects the electrical components and connections.

Examples of components often combined in EVs:

- Combined Charging Unit (CCU) or Power Control System (PCS) - DC DC Converter with Onboard Charger
- Inverter with Converter – DC DC converter with the motor inverter.
- Charger Assembly with Junction Box - the Onboard Charger with the Junction Box.

EV Specific Control Modules

There can be various control modules within a vehicle. These operate like small computers receiving signals and controlling some of the vehicle functions. Some of these are only found in EVs.

Examples of EV specific ones are the Battery Management Controller, Vehicle Control Module/Unit, Vehicle Sound Pedestrian Control Unit.

Charging Cable

The external charging cable for connecting charge points to the EV. Some EVs may come with more than one for connection to different types of charge point.

Charging Socket

Charging Socket would include socket and cables.

High Voltage Cables

In vehicle for carrying voltage to battery and from battery out to other functions. High Voltage Cables (over 60 volts DC or 30 volts AC) are coloured orange.

AC Compressor or Heat Pump

In an EV this is a high voltage component, powered by the battery. An EV would have an AC Compressor or a Heat Pump, with both parts looking similar. An AC Compressor would provide cooling, a Heat Pump both heat and cooling.

Coolant Lines

Due to the nature of what needs to be cooled within an EV (battery, potentially other HV components) Coolant Lines will be different in an EV to an ICE vehicle.

ABS Unit/Pump/Controller

Similar to ICE but more efficient in an EV and not interchangeable.

Axle

May be different in an EV to an ICE due to varying weight and components in the vehicle.

PTC (Positive Temperature Coefficient) Heaters

Provides heat in an EV - as there is no engine to provide thermal energy.

PTC heaters can be found in all types of vehicle. In the marques surveyed, in BEVs they tended to be high voltage and as such different to ICE Vehicles. In some HEV/PHEVs they may be low voltage e.g. 12v systems.

Power Steering Boxes/Steering Motor

May or may not be different in EVs. In some EVs it is different to account for the additional weight inherent in BEVs.

Brake Pads, Shoes and Callipers

Some EVs may have specific pads & shoes, in others they would be the same as that found in ICE vehicles. Some EVs do not have Brake Shoes.

Brake Master Cylinder

In some BEVs the Brake Master Cylinder is the same as in an ICE vehicle, in others it will be different. An iBooster (Vacuum-independent electromechanical brake booster) takes the place of control module, master cylinder and brake booster, it will be common in EVs, although not EV specific.

Heating Resistor

Same part as used in ICE for the majority of marques surveyed. Kia differed in that a control module is employed where a field effect transistor would be used in their ICE vehicles.

Appendix D: Mandatory Removal of Parts and Components from End-of-Life Vehicles as per the Proposal for a Regulation on Circularity Requirements for Vehicle Design and on Management of End-of-Life Vehicles.

Annex VII, PART C: MANDATORY REMOVAL OF PARTS AND COMPONENTS FROM END-OF-LIFE VEHICLES Parts 1-12: ATFs shall ensure these parts are removed from ELVs prior to shredding. Parts 13-19: Do not have to be removed pre-shredder, if it can be demonstrated that post-shredder technologies separate materials from these parts as efficiently as manual dismantling processes or semi-automated disassembly processes.		
1	Electric vehicle batteries	EV Battery
2	E-drive motors, including their casings and any associated control units, wiring, and other parts, components and materials	Electric Motor
3	SLI batteries as defined in Article 3, point (12), of Regulation (EU) 2023/****[on batteries and waste batteries]	Lead Acid Starter Battery (potentially Li-ion in some marques)
4	Engines	N/A for BEV but would apply to PHEV and HEV
5	Catalytic converters	N/A for BEV but would apply to PHEV and HEV
6	Gear boxes	Reducer/Gearbox
7	Windshields, rear and side windows made of glass	Yes, same as ICE
8	Wheels	Yes, same as ICE
9	Tyres	Yes, same as ICE
10	Dashboards	Yes, same as ICE
11	Directly accessible parts of the infotainment system, including sound, navigation, and multimedia controllers, including displays of a surface greater than 100 square centimetres	Yes, same as ICE, instrument panel and infotainment system
12	Headlights, including their actuators	Yes, same as ICE
13	Wire harnesses	Yes, same as ICE
14	Bumpers	Yes, same as ICE
15	Fluid containers	BEV would not have fuel tank but would have other containers for liquids like coolant
16	Heat exchangers	AC Condenser/Radiator. Potentially PTC Heaters.
17	Any other mono-material metal components, heavier than 10 kg	Unknown
18	Any other mono-material plastic components, heavier than 10 kg	Unknown
19	Electrical and electronic components: -inverters of the electric vehicles -printed circuit boards with a surface area, larger than 10 cm^2 -photo-voltaic (PV) panels with a surface area, larger than 0.2 m^2 -control modules and valve boxes for the automatic transmission	Inverters/Onboard Chargers Likely to apply to Inverters and Converters in the vehicle

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