Remanufacture, refurbishment, reuse and recycling of vehicles: Trends and opportunities

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Executive Summary

The automotive sector plays an important role in the Scottish economy, despite the lack of passenger vehicle production facilities. Vehicle production continues to be a feature of the Scottish economy in the bus and heavy plant sectors with supporting supply chains. A large number of people are also employed in vehicle sales, service and repair. There are a number of examples of companies that remanufacture and refurbish vehicle parts, such as automatic transmissions and engines. At the end of life of the vehicle, dismantling, parts reuse and material recycling enterprises also contribute value and employment to the Scottish economy.

Long and short term trends faced by the automotive sector

The automotive sector is a significant user of materials and energy in production. Similar to other production sectors, it faces considerable challenges arising from a growing global population which is expected to increase from six billion people today to around nine billion by 2050. In addition to the growth in overall population numbers it is also predicted that consumption per person will increase as developing nations become richer. The combination of these two trends will result in greater demand for resources and subsequent price increases and issues with security of supply (of both energy and scarce materials).

The issue of increasing energy use (with the obvious link to fossil fuel use and resulting carbon dioxide emissions) and broader increasing pressure on finite resources is attracting interest from governments, business and civil society around the world. This is resulting in new policies and regulation relating to resource efficiency and climate change. There is also evidence of businesses taking action to address these strategic challenges and some consumers changing their buying behaviour.

Technological change will also result in vehicles becoming ever more complex, with a shift from mechanical parts to increasingly hybrid mechanical/electronic (mechatronic) parts. These will have higher residual values, meaning the economic case for reuse, repair, refurbishment and remanufacture improves against the alternative of material recycling.

In addition to these longer term trends, the passenger vehicle and light van sector also faces short term challenges associated with meeting (2015) reuse and recovery targets set by the End of Life Vehicle Directive.

Medium to long term opportunities for the Scottish economy

A range of opportunities for enterprises and the wider Scottish economy are possible, through a shift in the current „linear economic model' to a „circular economic model'. In the context of a vehicle, a „linear economic model' describes where material is extracted, converted to parts and components then assembled to be used by the consumer until it reaches end of life. It is then disposed of (with the majority of material being recycled, displacing further extraction but still requiring energy in future production processes). A

„circular economic model' describes a situation where the material is kept in use by the market as parts and components for a much longer period and more value obtained from it. This reduces both the rate of raw material extraction and the energy used to convert raw materials into functional parts and components. Parts and components are reused, repaired, refurbished and remanufactured. The decision about which process to use depends on several factors including safety, performance and the economic case. The speed with which parts and components return to the market (and are therefore utilised and generate value) and the energy used in the process, differs between reuse, repair, refurbishment and remanufacture.

Figure 1, below, compares and summarises the alternative linear and circular material flows.

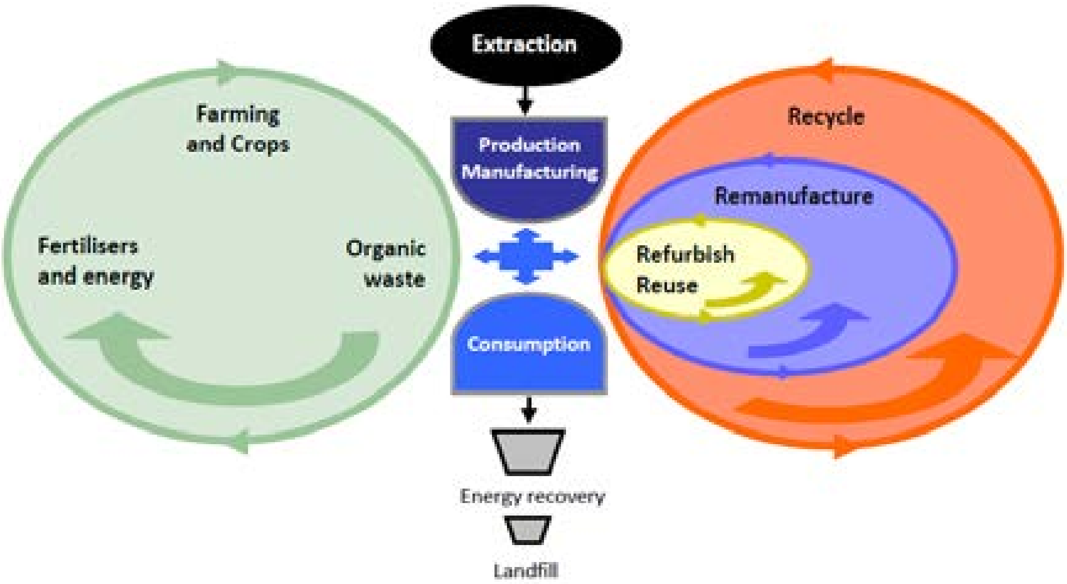

Figure 1 - Linear and circular flows of material[1]

Moving to a circular model of material flow is recognised by many leading industrial countries as a potential source of competitive advantage. For example, China, United States and Singapore all have (or intend to introduce) either high level policy commitments and/or research centres of excellence in this area.

A recent report has highlighted the automotive sector as being the largest beneficiary of total net material cost savings of between USD 340 billion – 630 billion per year. This cost saving is predicted to be made, by a range of complex durable products with medium life-spans, through a shift to an economic model where material is circulated in the manner described above[2].

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[1] Duty of Care – A Code of Practice, Scottish Government, October 2012
[2] „Towards the Circular Economy', Ellen MacArthur Foundation, Vol.1, Fig 8, p.66, 2012

Figure 2, below, simplifies and summarises the wide range of potential opportunities to generate value and create skilled employment opportunities in Scotland.

	Supply chain position				
Automotive sector segment	*OEM Remanufacturer*	*Tier 1 Remanufacturer*	*Independent Remanufacturer*	*OEM contracted refurb, service and repair garage*	*Vehicle Disassembler*
All vehicles (assuming a circular economy model is followed for passenger vehicles/light vans, trucks and buses and heavy plant)	Design for remanufacture Continuous ownership of vehicles Value generated from service fees from consumers Remanufactures vehicles using remanufactured parts and components New vehicle production also uses remanufactured parts and components, where possible Service level agreements for new and remanufactured vehicles Provides information to others in the supply chain about disassembly, quality checking, sub-component sourcing, remanufacture and testing	Obtain cores from vehicle disassemblers, core brokers and OEM contracted refurbishment, service and repair garages Maintains ownership of some key core parts (e.g. batteries) and generates value through service fees from the OEM Supply remanufactured parts to OEM for new vehicle production and vehicle remanufacture Service level agreements for new and remanufactured parts and components Provides information to others in the supply chain about disassembly, quality checking, sub-component sourcing, remanufacture and testing	Focus on core parts not owned by Tier 1 remanufacturers High level of mechatronic skills required Supply to OEMs directly and to OEM contracted refurbishment, service and repair garages Source from vehicle disassemblers and OEM contracted refurbishment, service and repair garages Access information from OEMs and Tier 1 suppliers about disassembly, quality checking, sub-component sourcing, remanufacture and testing	Local refurbishment, service and repair garages contracted to OEMs to ensure vehicles are properly maintained to optimise utilisation Source remanufactured parts and components from Tier 1 and independent remanufacturers Provide used core parts to Tier 1 and independent remanufacturers Once a vehicle can no longer be refurbished or repaired it is passed to vehicle disassemblers Access information on refurbishment, service and repair from OEMs and Tier 1 suppliers	Large volume automated/ semi-automated disassembly plants Source vehicles which are no longer economic to refurbish or repair from OEM contracted refurbishment, service and repair garages Removal of parts and components - cores then go to Tier 1 remanufacturer (if they retain ownership) or to independent remanufacturers (direct or via core brokers) Core vehicle 'skeleton' returned to OEM for use in vehicle remanufacture High level of material segregation for non core elements of the vehicle Zero waste to landfill
Supporting activities	*Finance and risk management* Provision of finance and insurance products to enable OEMs to maintain vehicle ownership and consumers to pay using a service/performance model. Provision of risk management services to support warranties on remanufactured parts and components				
	Consultancy A wide range of supporting consultancy services will be required including: business process; material science; standards accreditation; carbon trading/carbon capture; lifecycle analysis and costing, etc.				
	Education and skills (development and delivery) Development and delivery of training and education for industry on remanufacture and reuse - to develop company specific competencies (existing enterprises and new entrants). Development and provision of wider educational materials for schools, colleges and universities to attract people into reuse, repair, refurbishment and remanufacturing sectors				
	Tool developers Development of specialist diagnostic, processing and testing equipment to support disassembly, service, repair, refurbishment and remanufacturing operations. This will include physical tools/equipment and software tools				
	Reverse logistics (e.g. core brokers) Specialist handling, transportation, storage and supply of core parts from disassemblers and OEM contracted refurbishment, service and repair garages to Tier 1 and independent remanufacturers. Reverse logistics also for core vehicle 'skeleton' back to OEM remanufacturer from vehicle disassemblers				
	Information and Communication Technologies Development and supply/maintenance of ICT systems to enable knowledge sharing amongst different parts of the supply chain about refurbishment, service, repair, disassembly, quality checking of parts/components, sub-component sourcing, remanufacture and testing				
	Repurposing, upcycling and downcycling In addition to reuse, repair, refurbishment and remanufacture of vehicles, parts and components for their original use, there is also a market for repurposing (e.g. Electric car batteries used for wind turbine electricity storage), upcycling (e.g. designers producing consumer goods from parts) and downcycling (e.g. shredding and mechanical separations of parts not suitable for any other purpose)				

Figure 2 - Potential automotive supply chain based on a circular economy model

This research report identifies a number of opportunities which would be present in such future supply chain, including:

1. Development of refurbishment, service and repair operations at the vehicle level
2. Development of remanufacturing operations at the part, component and sub-component level
3. Development of large scale, semi-automated, disassembly plants for vehicles no longer suitable for refurbishment, repair and service
4. Development of services around financial instruments to support different business models
5. Development of numerous consultancy services including business process engineering, material science services, standards accreditation, carbon trading/carbon capture
6. Development and delivery of education and skills training aimed at schools, colleges, universities and businesses
7. Development of specialist diagnostic, processing and testing equipment to support disassembly, service, repair, refurbishment and remanufacturing operations
8. Development of reverse logistics services taking into account concerns over the increasing need for safe handling, storage and transportation of parts and components with increasing electronic composition
9. Development and maintenance of ICT systems for information sharing between different parts of the supply chain about vehicle and part design, disassembly, quality checking, sub-component sourcing, remanufacture and testing
10. Development of enterprises established to repurpose vehicle components and parts (e.g. electric batteries to renewable energy storage uses)
11. Development of enterprises engaged in upcycling of vehicle parts and components (e.g. artists and designers producing consumer goods)
12. Development of downcycling operations with greater expertise in material recovery (e.g. extraction of rare earth elements from magnetic components)

Each part of the potential future automotive supply chain is described in greater detail in section seven along with further discussion on the areas of opportunity.

Short term challenges faced by dismantlers and shredders

In addition to the medium to long term trends and challenges faced by the wider automotive sector, this research report highlights the short term challenges faced by parts of the sector involved in reuse and recycling of parts and components (vehicle dismantlers and shredders).

There are around 140 registered end of life vehicle dismantlers (or Authorised Treatment Facilities) based in Scotland and four large mechanical shredders. These enterprises are estimated to process a minimum of 100,000 end of life vehicles per annum, in addition to other metal containing products, such as waste electrical and electronic equipment. Some of these dismantlers work with compliance schemes operated on behalf of passenger and light van producers and importers to report on performance against targets set within the End of Life Vehicle Directive. Section three provides more details about the relevant legislation and market structure.

The End of Life Vehicle Directive has set a target of 85% reuse and recycling and 95% reuse and recovery by 1st January 2015. Current UK performance achieves approximately 85% reuse and recovery of End of Life Vehicles.

One of the key issues for the sector is how the extra 10% reuse and recovery will be achieved. Currently the materials not reused or recovered are contained within waste output from shredders known as Automotive Shredder Residue or simply Shredder Residue (as it contains residue from other input materials such as waste electrical and electronic equipment). Currently, in Scotland, the most economic way to treat this residual material is typically to send it to landfill. It is estimated that total shredder residue produced in Scotland is around 60,000 tonnes per annum which represents a significant disposal cost to shredders and a loss of material to the economy. To achieve the 2015 End of Life Vehicle Directive target of 95% reuse and recovery (with 85% being reuse and recycling) the use of landfill must be reduced. This can be achieved by either increasing reuse and recycling or sending more material for energy recovery (or a combination of both).

During the research carried out for this report, dismantlers highlighted several current issues that impact on their business. The key issues reported include:

- The apparent lack of cross checking by the Driver and Vehicle Licensing Agency about whether a Certificate of Destruction has been issued for each end of life vehicle. When scrapping a vehicle, the last owner is required to return a completed V5C form to the Driver and Vehicle Licensing Agency, advising of transfer of ownership. They are also meant to receive a Certificate of Destruction from the Authorised Treatment Facility to which ownership is transferred. Unauthorised scrap vehicle purchasers are not able to issue Certificates of Destruction and there does not appear to be any cross checking carried out to establish when this occurs. Additionally, there does not appear to be any sanctions against last owners who do not obtain a Certificate of Destruction. Putting such cross checks in place would increase the barriers for unauthorised scrap vehicle purchasers and increase the likelihood that scrap vehicles will be depolluted by Authorised Treatment Facilities

- There is limited economic incentive for dismantlers to remove non-metallic parts (such as plastic bumpers or glass) from end of life vehicles prior to selling on to a shredder. Only where the part can be sold for reuse is there sufficient return to justify removing it. Removal of non-metallic parts and components for material recycling is generally not economically justified due to a combination of labour required to carry out such dismantling and the fact that a higher value can be achieved through selling the material to a shredder than to a specialist glass or plastics recycler (this occurs because shredders tend not to offer a different price per tonne for vehicle hulks with non-metallic parts and components removed compared to those where they are still attached)

- There are market barriers to the use of reused parts and components. These relate to concerns about standardised quality and safety of parts, availability on short order times, uncertainty about returns policies and a lack of transparency about pricing structures

Further details on the current state of the dismantling and shredding sectors in Scotland, comparisons with end of life vehicle practices in other countries and markets for dismantler and shredder outputs, can be found in sections three to six of this report.

Short term opportunities

In response to the short term issues identified for the dismantling and shredding sectors, a number of opportunities were investigated and their economic and environmental impacts assessed, relative to a business as usual scenario. Under the business as usual scenario, it was estimated that the economic value generated through parts reuse and material recovery from end of life vehicles, in Scotland, (net of residue disposal costs) was around £32 million per annum in 2011, rising to £45 million per annum by 2030. Net environmental benefits of material recycling were estimated at around £9 million per annum in 2011, rising to over £13.5 million per annum by 2030. The research project created a model to estimate these figures and then compared against three potential short term opportunities.

The opportunities assessed included:

- Introduction of a Post Shredder Technology plant that would be dedicated to processing shredder residue material. The plant would recover some of the non-metallic (and residual metallic) materials contained within shredder residue, with the remainder used to produce a solid recovered fuel for use in energy recovery
- Introduction of a plasma gasification plant which could accept shredder residue in addition to other wastes (so is not as constraint on feedstock type as the Post Shredder Technology plant). The plant is purely energy recovery with no additional material recycling (other than the residual solid output being used as an aggregate)
- An increase in 50% in parts and components reuse above current levels. This opportunity is supported by the introduction of a Publicly Available Specification on reused parts to help reduce market concerns about quality

Figure 3, below, summarises the estimated economic and environmental impacts of the scenarios relative to the business as usual impacts.

Short term commercial opportunity	Minimum viable capacity	Estimated investment	Impact shown as relative to 'business as usual' case		
			Additional annual gross economic impact (net of disposal costs) by 2030	Change in the net annual environmental impact by 2030 - negative shown in ()	Combined change in annual social impact (economic + environmental) by 2030
Scenario 1 - Post Shredder Technology plant	60,000 to 100,000 T p.a.	£20 million to £25 million	£3.35 million	£0.06 million	£3.41 million
Scenario 2 - ASR plasma gasification plant	50,000 T p.a.	£20 million	£6.22 million	(£1.57 million)	£4.65 million
Scenario 3 - 50% increase in parts reuse	N/A	£65,000 for PAS and ~ £2,000 - £5,000 annual fees per ATF	£4.72 million	Not calculated due to lack of data	Not calculated due to lack of data

Figure 3 - Overview comparison of short term opportunities

The above estimates suggest that the increased economic returns from a 50% increase in reused parts and components represents a good return on the initial investment. This does not quantify the time and effort required by dismantlers, insurers, service and repair garages and others in setting up the necessary infrastructure.

It should also be highlighted that there are investment risks in establishing either a Post Shredder Technology plant or plasma gasification merchant plant to treat shredder residue. These risks relate to the medium to long term trends highlighted earlier where less material would flow through the sector for recycling and energy recovery. If the automotive sector shifts to a model where there are higher levels of reuse, repair, refurbishment and remanufacture then the available feedstock for recycling and energy recovery plants will reduce. The shredding sector is unlikely to enter into long term supply contracts with the types of facilities described in scenarios 1 and 2, above. This means such facilities could face difficulties in obtaining both initial investment and input material in the medium to short term.

The use of Post Shredder Technology and/or energy recovery facilities will, however, play an important role in achieving the 2015 End of Life Vehicle Directive target of 95% recovery. A number of these facilities have already been developed in England and it is not yet clear how the situation will develop in Scotland. One of the potential policy actions, developed as part of this report, proposes funding for a technical study(s) to investigate the feasibility of shredder residue recycling plant as an add on to existing shredder operations or at a merchant plant scale that could be commercially feasible at the estimated Scottish arisings of shredder residue of around 60,000 tonnes per annum.

Potential policy actions

In response to the issues and opportunities identified during this research project a number of potential policy actions have been developed. These are summarised in figure 4, below, and discussed in greater detail in section nine.

Potential Policy Actions
1 Dissemination and further engagement with the supply chain to identify opportunities, stimulate supply chain networking and collaboration and support further feasibility studies and pilots
2 Stimulate and support moves towards a circular economy
2.1 Work with the Technology Strategy Board to identify short term pilot studies in the area of 'new designs for a circular economy'. This could provide funding support for feasibility studies by different parts of the Scottish supply chain
2.2 Investigate the scope for a Centre of Remanufacturing Excellence to provide a focus for academics, researchers, enterprises and regulators with an interest in remanufacturing in the automotive sector
2.3 Investigate options for other innovation and R&D hubs to address challenges and opportunities in areas beyond remanufacturing, such as reuse, repair and refurbishment
2.4 Support standards development for remanufacturing to help reduce market barriers and increase demand
2.5 Investigate the use of public procurement to support the circular economy by stimulating demand for remanufactured refurbished, repaired and reused vehicles, parts and components
2.6 Investigate education and skills needs for a circular economy to ensure relevant skills and capabilities are available to existing and new parts of the supply chain
2.7 Investigate options to support repurposing and upcycling for parts and components no longer suitable for reuse, repair, refurbishment or remanufacture to help maximise value created in Scotland
2.8 Consider longer term potential policy actions to support a circular economy to ensure future regulatory and fiscal policy development aligns with the framework required to support a circular economy
3 Awareness raising amongst Authorised Treatment Facilities regarding compliance with the End of Life Vehicle depollution process to ensure the correct equipment and skills are available
4 **Enabling measures to support reuse of vehicle parts and components to remove barriers to specification and procurement**
4.1 Supporting the development of a Publicly Available Specification for reuse to reduce market barriers and increase demand
4.2 Develop the market for parts and components reuse in the private sector by supporting pilots to establish best practice
5 Provide funding for a study into shredder residue recycling plant to investigate commercially viable technical solutions for individual shredders or a merchant facility (at a scale that matches individual shredder/Scottish arisings of shredder residue)
6 Other measures to improve the level and quality of recycling to minimise material lost to landfill and maximise economic return
6.1 Instigate changes to the DVLA process to only deregister based on a COD to reduce the availability of End of Life Vehicles to unauthorised operators
6.2 Introduction of an End of Life Vehicle funded system to incentivise last owners to deal with Authorised Treatment Facilities
6.3 Introduction of an End of Life Vehicle funded system to incentivise Authorised Treatment Facilities to achieve specified levels of material separation prior to shredding
6.4 Introduction of regulation to mandate removal of specified materials at the dismantling stage to ensure higher quality of plastic and glass are recovered
6.5 Support a pilot project to assess the impact of shredder pricing differentials to incentivise dismantlers to remove specified non metallic materials prior to shredding
6.6. Introduction of an landfill ban on Automotive Shredder Residue or inclusion of it in a higher landfill tax band to support the development of alternative treatment technologies
6.7 Support the development of markets for non metallic materials recovered at the dismantling stage through public procurement to incentivise dismantlers to remove items such as plastics and glass prior to shredding
7 Support studies into the recovery and reuse of high value metals and rare earth elements to obtain more value from materials and reused/remanufactured high value parts and components

Figure 4 - Summary of potential policy actions

These potential policy actions have been developed in response to issues, opportunities and potential solutions identified by representatives of a cross section of the Scottish automotive supply chain (including dismantlers and shredders), downstream material users, regulators, policy makers.

Consideration of this research report is intended to inform the automotive sector supply chain and government in Scotland of the opportunities arising from short, medium and long term trends. The potential policy options are designed to support the development of these opportunities for the economic, social and environmental benefit of Scotland. The research suggests there is a significant opportunity in the medium to long term to generate value and create jobs through a move to an economic model where fewer resources are used. The research also highlights the short term need to support the UK 2015 End of Life Vehicle target of 95% reuse and recovery by diverting more shredder residue from landfill. The potential policy actions address these key challenges and opportunities.

This research report was produced by Optimat Limited with funding from the Scottish Government. The views, opinions, conclusions and recommendations are those of Optimat Limited and not necessarily those of the Scottish Government. Whilst every reasonable effort has been made to ensure the accuracy of the information presented, Optimat Limited is in no way liable for any subsequent use of any part of this report by third parties

List of Acronyms and Abbreviations

ASR	Automotive Shredder Residue
ATF	Authorised Treatment Facility
BAU	Business As Usual
BREF	Best Available Technology Reference document
CAN	Controlled Area Networks
CAT	Catalytic Convertor
CFCs	Chlorofluorocarbons
CHP	Combined Heat & Power
COD	Certificate of Destruction
DVLA	Driver and Vehicle Licensing Agency
ECUs	Electronic Control Units
ELV	End of Life Vehicles
EV	Electric Vehicle
IPPC	Integrated Pollution Prevention and Control
LAB	Lead Acid Battery
MSW	Municipal Solid Waste
OEM	Original Equipment Manufacturer
PAS	Publicly Available Specification
PCBs	Polychlorinated Biphenyls
PHEV	Plug-in Hybrid Electric Vehicle
PST	Post Shredder Technology
PVC	Polyvinyl Chloride
RDF	Refuse Derived Fuel
SEPA	Scottish Environmental Protection Agency
SRF	Solid Recovered Fuel
SR	Shredder Residue
TSB	Technology Strategy Board
WEEE	Waste Electrical and Electronic Equipment

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Table of Contents

1. Introduction

This report identifies trends and opportunities related to the remanufacture, refurbishment, reuse and recycling of vehicles and their component parts.

The report first considers the key long term global trends in automotive design, production, use and disassembly. This is detailed in section two.

Section three then considers the current technologies and practices used by ELV dismantlers and shredders in Scotland and section four reviews technologies and practices used in other geographical areas. Section five summarises and compares different ELV systems used in other countries. The current markets for ELV parts and materials are described in section six.

In the longer term, the opportunities around remanufacture and refurbishment are available to a wider range of businesses in the Scottish economy, including vehicle manufacturers, their supply chain and new entrants from other sectors (e.g. business with experience in electronics production and testing, logistics, financial product development and risk management). These opportunity areas are described in section seven.

In the short term, the opportunities are most relevant to businesses that dismantle and shred ELVs with increased parts reuse, improved material recovery and reduced costs associated with residue treatment being the key areas. These short term opportunities are described, evaluated and compared in section eight.

Finally, section nine identifies and describes a range of potential policy actions which could help businesses in Scotland take advantage of both short and long term opportunities identified in this report.

The report has been prepared by Optimat Limited with funding provided by the Scottish Government. The views expressed in the report are those of Optimat and are not necessarily the views of the Scottish Government.

1.1 Background

This research has been carried out in response to two main drivers. The first of these drivers relates to projected long term trends in global population growth and increasing wealth in developing nations which are predicted to drive demand for resources. With limitations on resources, such as energy and materials, this will increase prices, raise issues with security of supply and ultimately impact on national competitiveness of different economic sectors.

The second driver is the need for the UK to achieve the 2015 ELV Directive targets of 85% reuse and recycling and 95% reuse and recovery during 2015 and in subsequent years[3]. With current UK performance of approximately 85% reuse and recovery, this presents short term challenges and opportunities for the ELV dismantling and shredding sectors.

This research study seeks to examine the implications of both of the above drivers.

1.2 Research objectives

The specific objectives of this study are to:

- Better understand the nature of the commercial opportunities related to remanufacture, refurbishment, reuse and recycling of vehicle materials and parts arising from long term trends in the wider automotive sector
- Provide evidence about commercial opportunities for the vehicle recycling industry in Scotland arising from the short term requirement to meet the 2015 ELV (End of Life Vehicle) Directive targets (including indicative economic and environmental benefits and costs)

1.3 Key research questions and method

The research method used to address the above objectives consisted of a number of activities requiring telephone and face to face interviews and secondary research.

Assessment of the longer term trends and opportunities arising from changes in vehicle design, production, use and disassembly:

- Identification of the key long term trends
- Consideration of the circular economy approach as a solution
- Detail on where the automotive sector (including ELV dismantlers) is already taking a circular approach
- Key features of a circular approach in the automotive sector
- Identification of the current and potential future supply chain frameworks
- Circular approaches in other countries
- Opportunities and benefits in the automotive sector

[3] Article 7(2), Directive 2000/53/EC of the European Parliament and the Council of 18th Sept 2000 on end of life vehicles

An in-depth review of the current situation in Scotland including the identification of:

- The characteristics of the Authorised Treatment Facilities (ATFs) in Scotland in terms of what technologies and practices they currently use, volume of vehicles processed, comparison with current capacity, type and destination and stage of recovery of outputs (e.g. how much is exported for reprocessing?)
- What issues they face in achieving higher rates of component and material reuse/recycling and recovery (metals, tyres, fluids, plastics, interior fabrics, vehicle electronics not covered by the Waste Electrical and Electronic Equipment (WEEE) Directive)
- What issues they face in achieving higher values for these components and materials
- What plans they have to invest in new technologies and practices (and barriers to same)
- Current markets for ELV parts and materials

A review of current technologies and practices used in the rest of the UK and overseas to deal with key issues faced by the industry including:

- Increased plastics recovery through better separation processes
- Development of applications/markets for recycled plastics
- Increased recovery of fluids
- Improved tyre recovery processes
- Initiation of other rubber recovery processes
- Reduction of residual metallic content of shredder residue
- Initiation of glass recovery processes
- Recycling and recovery technologies to extract rare earth elements and valuable metals
- Development of energy recovery processes for automotive shredder residues (ASR)
- Development of post-shredder material recovery processes

A review of how the ELV sector has developed in other countries and any actions taken by the respective Governments to support and develop the industry:

- Comparison of different ELV funding systems used in EU countries
- Review of practices employed in different European countries

- Review the ELV system and practices used in Japan

The impact of projected changes to future vehicle composition on:

- The capability of current technologies and practices to achieve legislative targets
- The capability of current technologies and practices to maximise the value of components and recyclates
- The potential markets for reused components and recyclates in the UK and overseas

Modelling of baseline and projected inputs/ outputs from ELV dismantlers in Scotland assuming Business As Usual (BAU) operations:

- Estimating current arisings of ELVs and material composition in Scotland
- Identification of changes to projected vehicle composition and weight
- Identification of typical costs associated with the procurement of end of life vehicles, average revenue achievable through dismantling and shredding operations and costs associated with disposal to landfill
- Development of a basic spreadsheet-based model to enable BAU and alternative scenarios to be compared

Modelling and comparison of the short term opportunities identified in the study:

- Economic benefit in terms of increased value from output materials and reduced costs of alternative disposal methods, such as landfill costs
- Environmental benefits in terms of avoided landfill and benefits/cost of recycling and recovery
- Comparison of the potential scenarios identified

The research questions were addressed through telephone interviews with over half of the ELV ATFs based in Scotland, face to face interviews with the majority of shredders based in Scotland and interviews with a number of other stakeholders from the wider automotive supply chain, material reprocessors, ELV experts from other countries and experts in remanufacturing from industry and academia. The study also benefited from industry representation (from both dismantler and shredder sectors) on the project advisory group. In addition to this, a wide range of published data was reviewed and references are included as footnotes throughout this report.

The remainder of the report details the findings from the above research questions.

2. Medium and long term trends

The following section describes some of the key medium and long term trends that will affect the automotive sector beyond the timescale of the 2015 ELV Directive targets. This covers a range of interlinked trends including political/legislative, economic, social, technological and environmental. The current activities of various parts of the automotive sector are then discussed and the key features of a „circular economy' described. A simplified supply chain model is then considered to frame the discussion on future opportunities. A brief overview of the response in other countries to the circular economy is provided. Finally, a summary of the potential benefits and opportunities are detailed.

2.1 Overview of key medium and longer term trends

2.1.1 Political/Legislative

By 2050, the global population is estimated to have grown to around nine billion people (almost a third more than current levels). Coupled with this growth in numbers is the projected increase in the spending power of developing nations[4]. The resulting increase in demand for a broad range of goods (including vehicles) will mean ever increasing raw material and fuel use.

[4] A resource-efficient Europe – Flagship initiative under the Europe 2020 Strategy, COM(2011)21, p.2

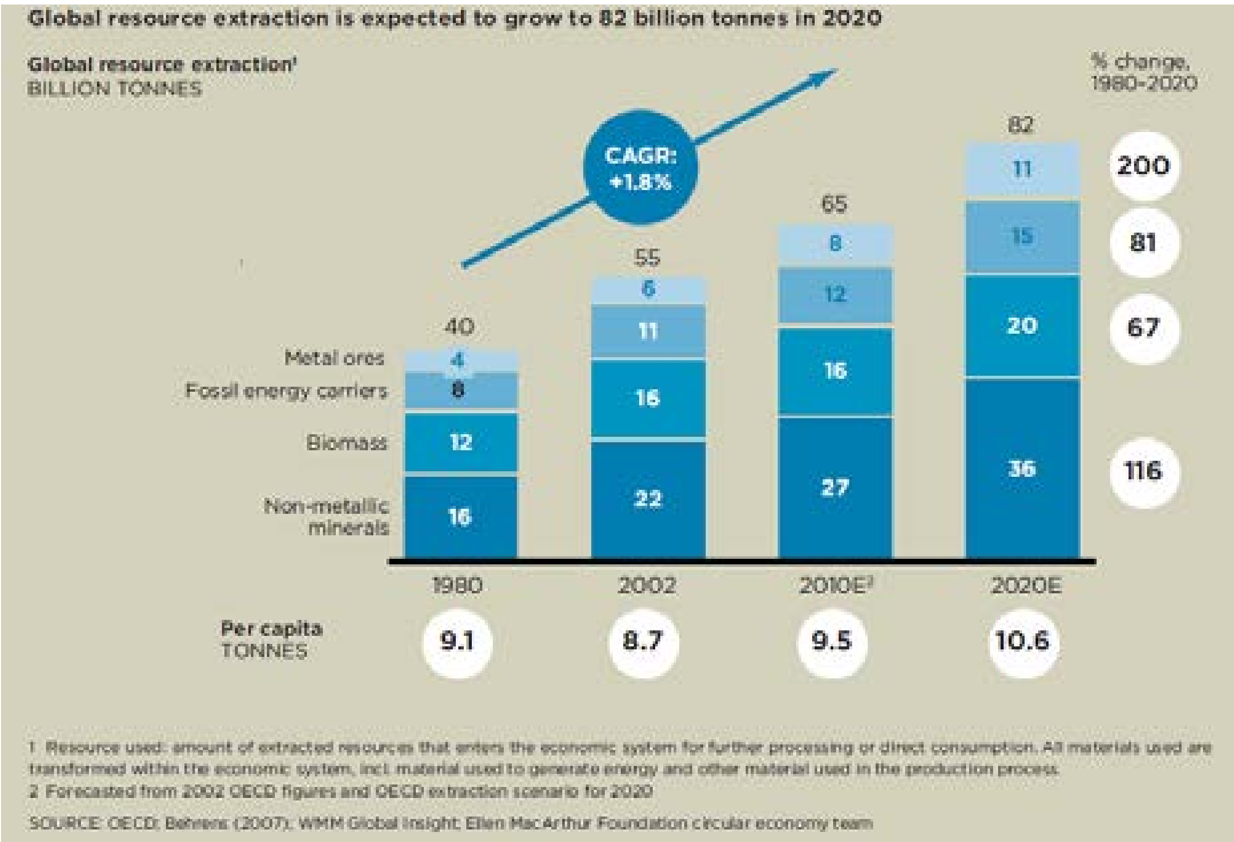

Figure 5 - Projected growth in global resource extraction to 2020[5]

The implications of these trends are the subject of increasing attention by national governments around the world seeking to develop appropriate framework conditions to address the challenges and opportunities that will arise. Increasing global demand for resources has important implications for security of supply and the sustainability of production industries. For example, the European Union has launched its Resource Efficient Europe initiative as part of the Europe 2020 Strategy. This provides a framework to ensure resource efficiency is addressed across a range of strategies, including energy, climate change, industry and transport, amongst others.

2.1.2 Economic

Closely linked to the increasing global demand for resources, such as fuels and materials, is the impact of this on input prices. The historical commodity price trends are shown in the figure below.

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[5] Towards the Circular Economy, Ellen MacArthur Foundation, Vol 1, Figure 1, p. 15, 2012

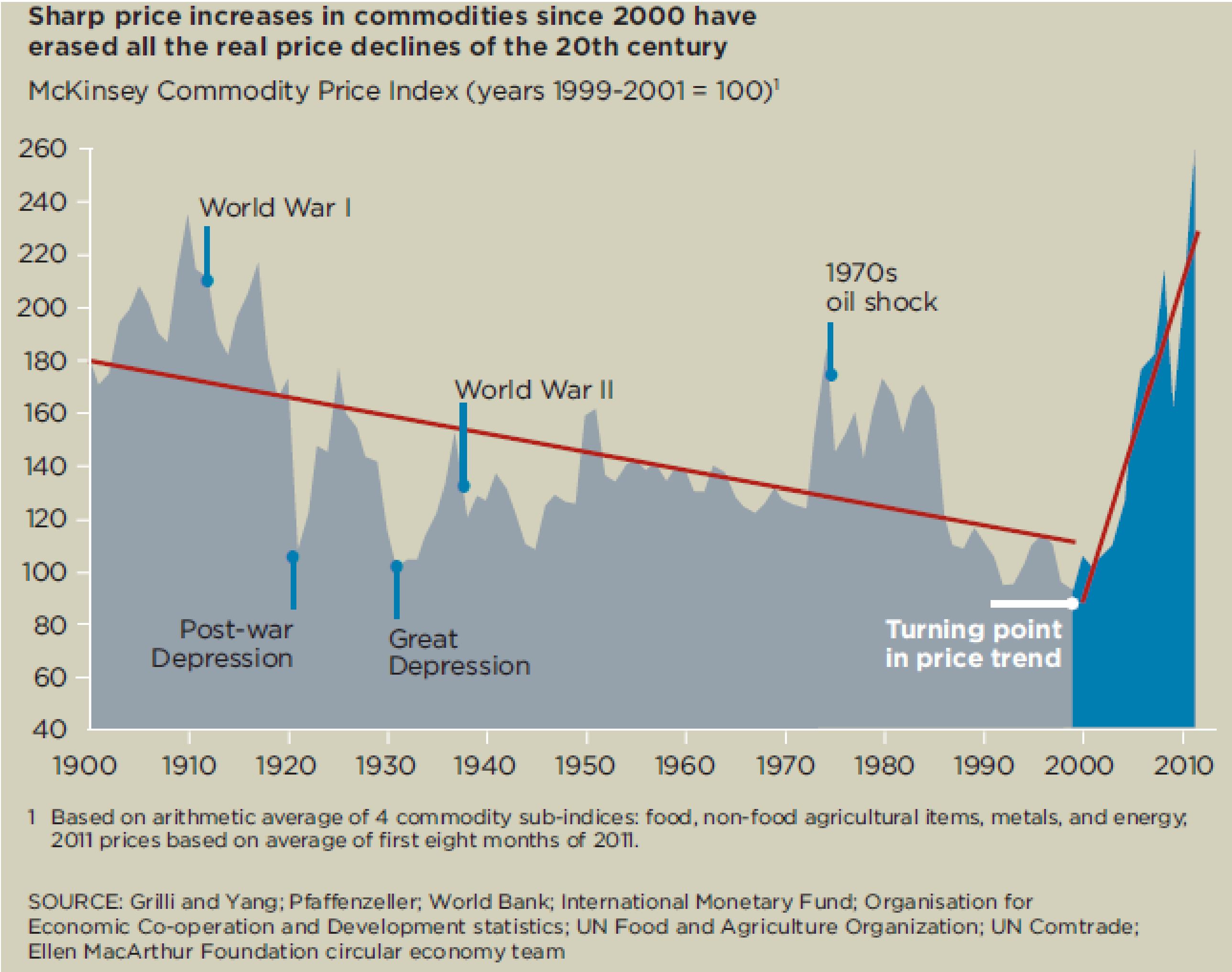

Figure 6 - Historical commodity price trends[6]

The above figure shows a decreasing trend in real commodity prices in the last century with this now being replaced by an upward trend. From an automotive producers perspective this means increases in input materials such as steel, copper and other valuable metals and rare earth elements. It also means increasing energy costs from the production process.

2.1.3 Social

The issue of the global trends of increasing population size and increasing consumer spending power in developing nations has already been discussed. In addition to this

[6] Towards the Circular Economy, Ellen MacArthur Foundation, Vol 1, Figure 4, p. 18, 2012

there are trends in consumer demand for vehicles which are also noteworthy. These include:

- Increasing demand for „low carbon' vehicles (fully electric and hybrid)
- Increasing demand for „infotainment', driver assistance and safety features within vehicles (e.g. DVD players, GPS systems and automatic proximity warnings)

Both of the above trends act to increase the electrical and electronic composition of vehicles.

2.1.4 Technological

In 1996 the automotive industry led by the industry body SMMT (Society of Motor Manufacturers and Traders) launched a major Foresight Vehicle initiative to help the UK automotive companies develop key technology to ensure global competitiveness. Financial support for technology developments was provided by the then Department of Trade and Industry. This £150m support underpinned developments in five key thematic areas identified by the SMMT automotive industry group. Over 100 projects involving 400 organisations in the sector developed key technology in the areas of:

- HEAFV – Hybrid, Electric and Alternatively Fuelled Vehicles
- EPT –Engine & Powertrain
- ASSET –Software, Sensors, Electronics & Telematics
- FASMAT –Advanced Structures & Materials
- DMAPs –Design, Manufacturing Processes & Sustainability

Many of these technologies have had, and are continuing to have, a significant impact on the product design and manufacturing process and have led to significant reform in the structure of the supply chain. Changes have also resulted in the vehicle product life cycle and end of life vehicle. The Vehicle Foresight Roadmap[7] is an industry supported information source on technologies which highlight how road vehicle markets, products, systems and technologies might evolve over the next 20 years.

To illustrate some of the consequences of the shift in technology being adopted by the automotive sector it is useful to consider the trends in ASSET technologies.

There has been a quantum shift in the proportion of electronics in the average vehicle. This has been fuelled by new products to control the vehicle such as engine, transmission, braking systems, on-board infotainment, radio, GPS, audiovisual displays etc, convenience systems parking aids, environmental controls, driver aids etc.

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[7] http://www.ifm.eng.cam.ac.uk/uploads/Research/CTM/Roadmapping/foresight_vehicle_v1.pdf

As these new ASSET technologies are introduced changes have happened in the on-board controls and communications systems and supporting network architecture. For example, the conventional wiring harness of a vehicle is a complex arrangement of electrical cables, plugs connectors etc. that delivers electrical power and communications. As more electronics are added to the vehicle the wiring harness has increased in weight. Currently the vehicle wiring harness for a mid-range car can weigh around 20 kg and can be double or triple this weight in a luxury vehicle. In addition to developments taking place to replace copper with aluminium to reduce weight in the cable wires, developments are taking place in Controlled Area Networks and associated bus communication standards (CAN bus) to make it possible for microcontrollers to communicate with each other in the automotive environment whilst reducing the complexity of the wiring loom.

The figure below shows a car without a CAN bus which shows the complexity of the wiring loom required[8].

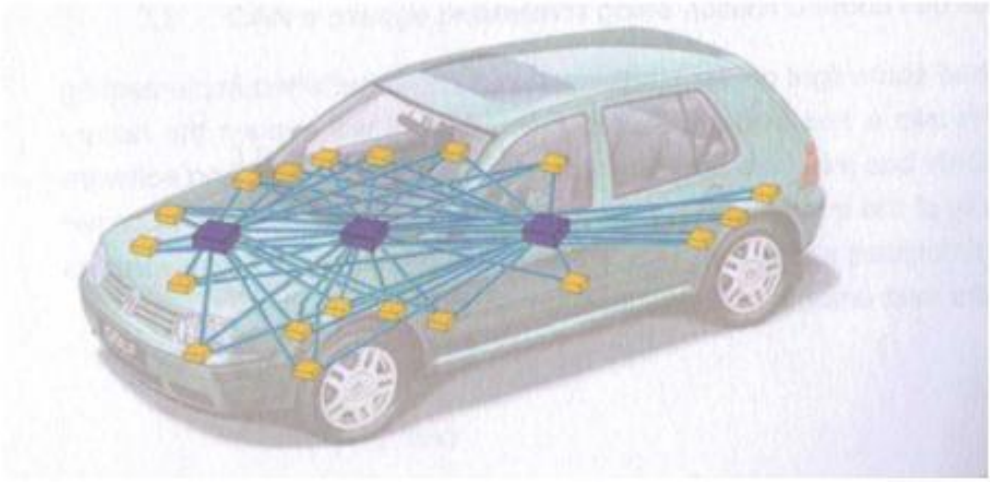

Figure 7 - Car without CAN Bus (Length and weight of wiring loom increases vehicle weight)

Separate Controller Area Networks are used to control and communicate with sensors and controls.

When a CAN bus hardware (a data bus comprising of two wires in twisted pair formation) is added it is possible to communicate with the separate Controller Area Networks and synchronise and integrate data whilst reducing the complexity, weight and cost of the wiring loom as shown in the figure below.

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[8] „European Automotive Remanufacturing – Technical Trends and Market Development' (Ed. Fernand J. Weiland), p.108 (Paper by Stef de Winter; Actronics, „Remanufacturing and CAN Bus Communication')

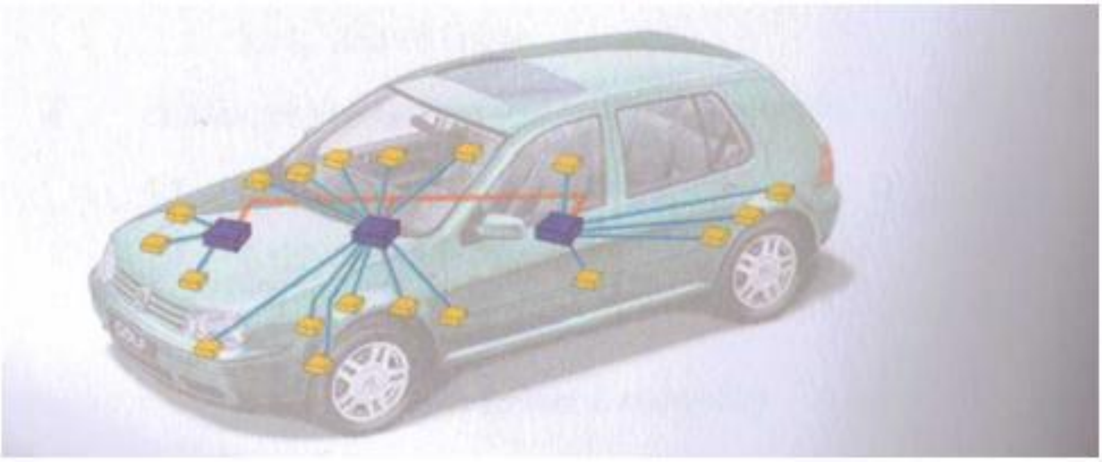

Figure 8 - Car with CAN bus

It is also possible to adapt this architecture and adapt to allow extra control options to be added.

An example of the types of sensors and controls in a CAN bus system is shown in figure 9.

Figure 9 - Example of CAN bus topology[9]

The consequence of this technology is that greater functionality is added without impact on the weight of the vehicle. The impact to the End of Life Vehicle sector is that the wiring loom is potentially easier to dismantle and the control units are a potential candidate for remanufacturing. This is a market that has scope and potential for development.

The development of asset technologies also underpins the changes envisaged in automotive mechanical, hydraulic and electrical components. These mechanical/hydraulic

[9] Freiberger, S. et al, „Reverse Engineering Technologies for Remanufacturing of Automotive Systems communicating via CAN bus', Journal of Remanufacturing, 2011 1:6 - http://www.journalofremanufacturing.com/content/1/1/6

systems are likely to involve a greater proportion of electric actuators that are electronically controlled and part of the CAN bus architecture. A recent publication suggests the following shift from mechanical to mechatronic components[10].

Current Technology	Replaced by
Passive components (switches, capacitors, inductors etc)	Active CAN bus components (sensors, microprocessors)
Starters	Start stop starters (electronically controlled)
Alternators	Combined generator/motor
Combustion engine	Electrical motor
Engine valves	Electrical variable valves
Hydraulic Power Steering	Electrical power steering
Mechanical pumps	Electrical pumps
Mechanical Fuel Injection	Electronically controlled fuel injection
Mechanical Turbochargers	Electronically controlled turbochargers
Brake vacuum booster	Electro-hydraulic booster
Brake master cylinder	Electrical braking cylinder
Handbrake	Electrical caliper
Manual gearbox	Electrically actuated gearbox
Shock absorbers	Electronically controlled shock absorbers
Automatic transmissions	Electronically controlled transmissions
Lead battery	AGM Battery/Lithium battery
12 Volts	48 Volt systems

Figure 10 - Mechatronic and electronic impact on components

The above projected change is likely to have greatest impact on smaller independent remanufacturers due to the changing skills and equipment required. It may also open diversification opportunities for companies involved in contract electronic manufacture.

2.1.5 Environmental

There are two main environmental trends linked to a growing population and increasing per capita consumption.

[10] „European Automotive Remanufacturing – Technical Trends and Market Development' (Ed. Fernand J. Weiland), p.135 (Paper by Fernand L. Weiland; FJW Consulting, „European Automotive Remanufacturing – Where is it Heading?')

The first of these is resource depletion. This includes fuel sources for energy generation and raw materials for production inputs. The ELV Directive has a reuse and recovery target for vehicles of 95% by 2015 and, if this is achieved, it will mean only a small percentage of materials being lost to landfill. There will, however, be embedded resources (e.g. water and energy) which are lost when materials are subject to energy recovery and even when recycled back to raw materials. Converting these raw materials back to parts and components, which can be used within a vehicle, will require further processing energy and the fuel to generate this energy.

The second main environmental trend is the increasing greenhouse gas emissions associated with increased production and consumption. There is a widely held view that greenhouse gas emissions should be cut by at least 80% by 2050 based on a 1990 baseline (e.g. this target is established in the Climate Change (Scotland) Act 2009[11]) and increasing consumption and production of goods, based on current business models, is likely to lead to increased emissions.

2.2 Potential responses to medium and long term trends

To begin discussing the potential responses to the long term trends it is useful to define some of the terminology used in this discussion. In the market for automotives, and their parts and components, the terms reuse, repair, refurbish, recondition and remanufacture are often used interchangeably or referred to as one homogenous group (using terms such as „green parts', for example). It is useful to draw a distinction between some of these terms[12]:

- Remanufacturing:
  - *"returning a used product to at least its original performance with a warranty that is equivalent to or better than that of the newly manufactured product"*
- Reconditioning/refurbishment:
  - *„Reconditioning is the process of returning a used product to a satisfactory working condition that may be inferior to the original specification. Generally, the resultant product has a warranty that is less than that of a newly-manufactured equivalent. The warranty applies to all major wearing parts"*
- Repair:
  - *„Repairing is simply the correction of specified faults in a product. When repaired products have warranties, they are less than those of newly*

[11] http://www.scotland.gov.uk/Topics/Environment/climatechange/scotlands-action/climatechangeact
[12] BS 8887-2:2009 Design for manufacture, assembly, disassembly and end-of-life processing (MADE). Terms and definitions - http://www.bbc.co.uk/news/uk-scotland-scotland-business-14249227

manufactured equivalents. Also, the warranty may not cover the whole product but only the component that has been replaced"

Where a product, part or component is reused then this is simply done without any of the above steps taking place.

The medium and long term trends, detailed previously, require a significant shift in the current approach to vehicle production and use. A key proposed response to these trends is detailed in a recent report by the Ellen MacArthur Foundation[13]. This report details the economic and business opportunities of a move from the current linear economic model to the so called „circular economy'. The current linear economic model refers to new goods being produced; value created through exchange of asset ownership (from producer to consumer) and then disposed of at end-of-life, perhaps with some element of material recycling. The circular approach moves away from just avoiding landfill and improving end of life recycling and moves more towards reuse, refurbishment and remanufacturing, as illustrated in the figure below.

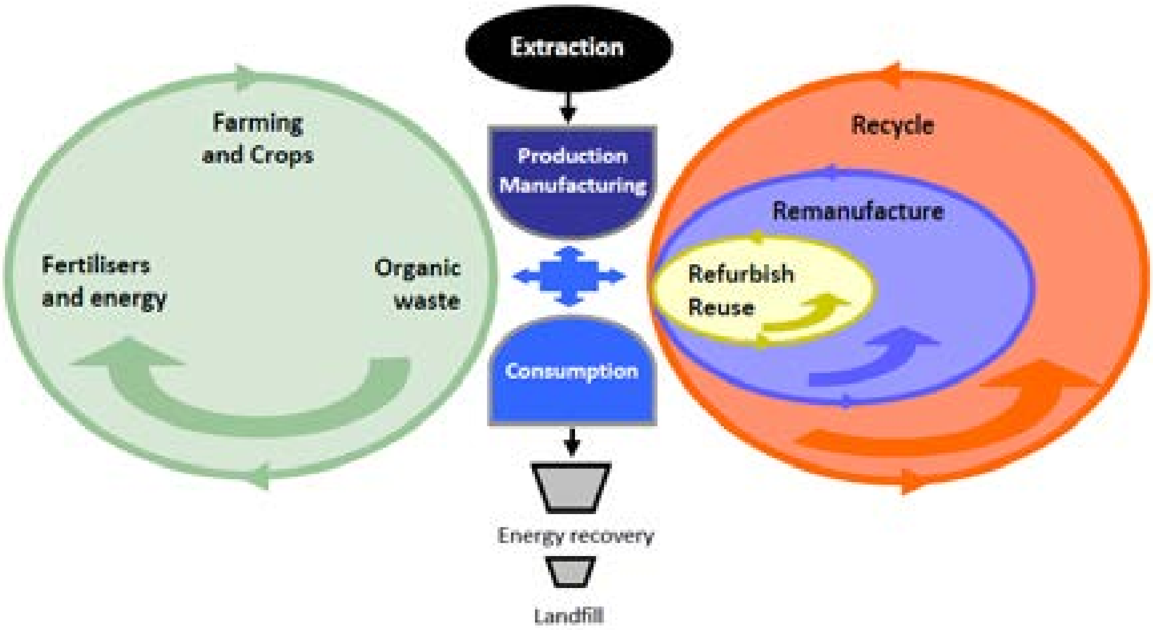

Figure 11 - Linear and circular flows of material[14]

The less a product has to be changed the quicker it can return to the market and the greater the savings on the use of labour, energy and materials (and associated environmental impacts).

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[13] „Towards the Circular Economy', Ellen MacArthur Foundation, Vol. 1, 2012
[14] Duty of Care – A Code of Practice, Scottish Government, October 2012

2.3 The automotive sector's approach to refurbishment and remanufacture

The automotive sector already has a high rate of end of life reuse and recycling, as described in detail later in this report. Refurbishment and remanufacture of automotive parts is already a significant industry providing substantial economic and environmental benefits. In EU 27 member countries, remanufacturing accounts for the employment of over 32,000 people (with the automotive sector representing the largest part of this activity) with the use of remanufactured parts and components conserving up to 85% material and energy use compared to new parts[15].

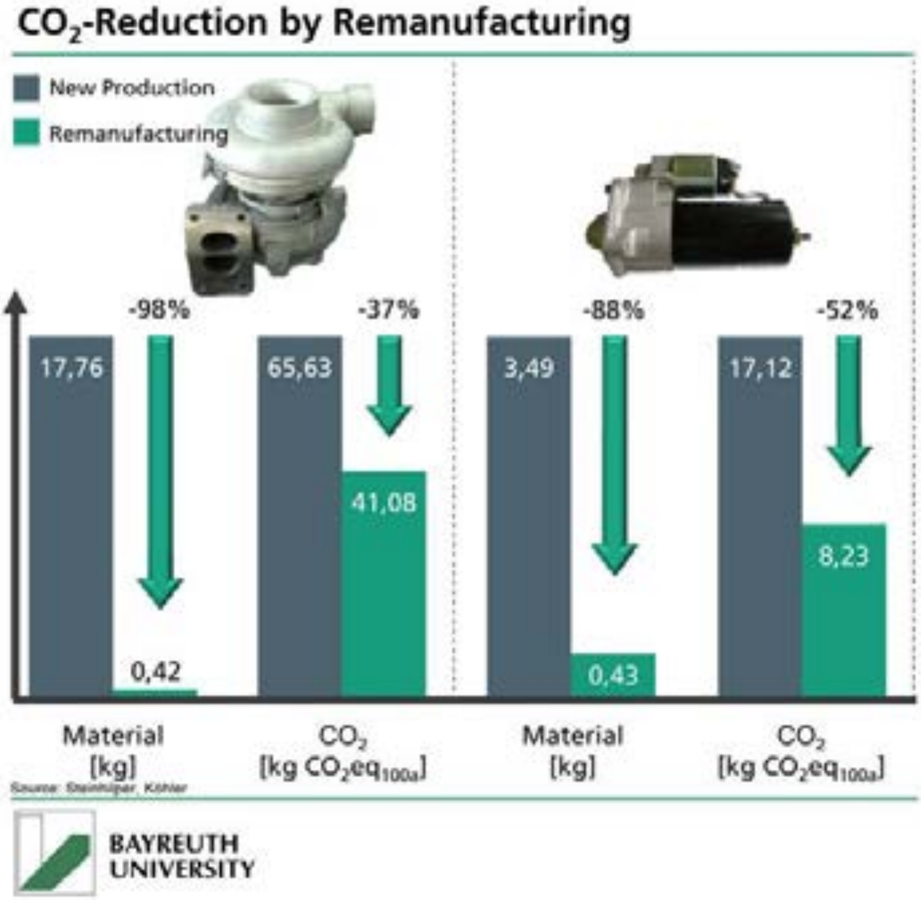

Figure 12 - Example material and CO_2 savings from use of remanufactured parts

Currently, only 10% of spare parts used in the aftermarket consist of remanufactured parts and very few are used in new vehicle production. There is, therefore significant room for growth in this area (and associated savings in CO_2 emissions).

[15] Automotive Parts Remanufacturer Association Europe - http://www.apra-europe.org/main.php?target=news&contentid=2077

Some examples of approaches of different automotive OEMs include:

Renault

Renault has established a remanufacturing plant near Paris. At this site there are several hundred employees remanufacturing a number of different mechanical subassemblies, from water pumps to engines. Renault obtains cores from its own distributor network from end-of life vehicle dismantlers as well as with new parts where required. The company has grow its remanufacturing operations into a 200 million euro business[16].

Nissan

In Japan, Nissan operate a programme called „Nissan Green Parts'. The programme covers a wide range of parts obtained from end-of-life vehicles and sold after reconditioning. In just over ten years to 2011, annual sales from Nissan Green Parts have risen from around 2 million yen to 1.61 billion yen[17].

Mercedes Benz (part of the Daimler Group)

Mercedes-Benz considers the ease of repair and remanufacturing of components at an early stage in the design. Worldwide, the Daimler Group has over 2,100 employees working in remanufacturing. Technologies used include arc wire spraying, laser cleaning and surface activation. Over 12,000 remanufactured parts and components are available[18].

Cummins

Cummins remanufacture engines and major components including electronics and mechatronics. Its remanufacturing facility in Cumbernauld is the company's base for targeting the European market. The company believes that remanufacturing will continue to be a growth area as engines and components increase in complexity[19].

Caterpillar

Caterpillar has been providing remanufacturing services for more than 20 years. The European Remanufacturing Centre of the Caterpillar remanufacturing Services Division is located in Shrewsbury. Using a host of remanufacturing technologies, the facility receives engines and a range of other components from customers, and cleans, refurbishes, reassembles and updates them in compliance with the exacting standards set by

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[16] „Towards the Circular Economy', Ellen MacArthur Foundation, Vol. 1, p.28, 2012

[17] http://www.nissan-global.com/EN/ENVIRONMENT/DEALER/GREEN_SHOP/RECONDITIONED_PART

[18] Kohler, H., „The Contribution of Remanufacturing to Resource Efficiency – Activities at Mercedes Benz, publicly available company presentation, 2012

[19] ReMaTecNews, Vol 11, No. 2, p.12, 2011

Caterpillar. The site remanufactures thousands of items each year, bringing significant environmental and cost benefits to Caterpillar and third-party customers[20].

Different parts of the automotive sector have different approaches to reuse, refurbishment and remanufacture. The section that follows considers the sector as three main parts: passenger vehicles/light vans; trucks and buses and; heavy plant.

2.3.1 Passenger vehicles/light vans

In the passenger vehicle/light van market, reuse is a fundamental part. Vehicles are reused by different owners until repair becomes uneconomic. Refurbishment of passenger vehicles tends to only occur in the classic car segment of the market. Current market conditions mean that it is uneconomic to completely remanufacture a passenger vehicle/light van and therefore this does not take place.

The leasing and short hire business models are mature practices in the passenger vehicle/light van market (with leasing particularly prevalent in the commercial sector). After a certain level of use these are not refurbished however, instead being sold on mainly to the domestic consumer market.

Moving away from considering the whole vehicle, this report will later discuss the existing market for a large variety of reused parts and components driven by dismantlers. The refurbishment of a smaller variety of higher costs parts and components is also a mature sector. For example, engines, transmissions, alternators, starter motors, brake callipers, etc.

The remanufacture of parts and components is also a growing sector. There is limited actual remanufacturing of passenger vehicle/light van parts and components that takes place in Scotland (although there is activity in remanufacturing automatic transmissions and torque convertors, for example). More parts and components (arising from end-of-life passenger vehicle /light vans arising in Scotland) do end up being remanufactured but this activity tends to take place in other countries with companies specialising in particular parts and components (for example, starter motors, alternators, hydraulic power steering systems, engines, transmission and gearbox systems, etc.). The route to these remanufacturers, for parts and components arising in Scotland is usually through core parts brokers.

The use of remanufactured parts and components is mainly in the aftermarket for passenger vehicles/light vans. There are, however, examples of remanufacturing sites being established near new vehicle production sites for the purpose of supplying parts and components for new vehicles. Such a remanufacturing facility has been established by Renault, near Paris, as described on page 16.

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[20] http://www.caterpillar.com/company/global-footprint/europe-africa-middle-east/united-kingdom/key-facilities

The emerging market for fully electric vehicles and hybrids is resulting in different end of life options being developed for the batteries that power the vehicles. These batteries are significantly more expensive than the lead-acid batteries used in conventional internal combustion vehicles and are have a residual life in other applications, such energy storage for excess renewable power generation.

2.3.2 Trucks and buses

As with passenger vehicles/light vans, the reuse and repair of buses and trucks is, obviously, a fundamental part of the market.

The higher capital cost of trucks and buses (relative to passenger vehicles/light vans) makes some refurbishment commercially viable in this part of the automotive market. For example, there are a number of companies in Scotland offering either refurbished fork-lift trucks or buses.

Remanufacturing is also present in this section of the market. For example, a company (based outside Scotland) specialising in the remanufacture of refuse collection vehicles.

Moving away from the reuse, refurbishment and remanufacture of the whole vehicle, there is an established market for part and component reuse, refurbishment and remanufacture (similar to the situation with parts and components from passenger vehicles and light vans). In this section of the market there are also examples of circular business models for specific parts. For example, in the truck and bus market a common practice is to lease the tyres from a supplier (which often retains ownership and is responsible for ongoing maintenance and replacement). These tyres can be removed and retreaded several times before then entering the rubber recycling chain. In some cases the haulier or bus company will opt to contract on a „pence per mile' basis to enable greater certainty of costs. There are clear incentives for the supplier to manage the tyre in such a way that extends the usable life (including retreading) for as long as possible.

2.3.3 Heavy plant

The term „heavy plant' covers a range of vehicles for different applications. For example, this part of the automotive sector includes vehicles for: construction and demolition; agriculture; mining and quarrying; industrial and military uses.

As with other parts of the automotive sector, the reuse and repair of vehicles is a fundamental part of the market. The higher capital cost of these types of vehicles mean that refurbishment and remanufacture of complete vehicles is also a significant feature. The use of short hire and leasing of heavy plant vehicles is also prevalent as maximising the utilisation of the vehicle is highly desirable for the owner of the asset.

The high value of individual parts and components in heavy plant vehicles also means that there is a mature market for reuse, refurbishment and remanufacture at this level. For example, Caterpillar has a well established remanufacturing operation for heavy plant vehicles which has grown by 8% to 10% in the last decade[21].

2.4 Key features of a circular approach in the automotive sector

Before discussing the opportunities for the automotive sector in following a more circular approach, it is useful to describe some of the key features of the „circular economy'. This section considers features of the design stage, innovation in the business models used, reverse logistics and enabling factors to support the transition from linear to circular approaches.

2.4.1 Design

The key features of design in a circular economy include:

- Design for disassembly (e.g. active disassembly, snap fasteners instead of weld/adhesive joints, etc.)
- Material selection to minimise toxic materials and enable recycling (e.g. using the same types of plastic polymer to ease recycling, reducing the use of PVC, etc)
- Standardisation and modularisation to simplify replacement (linked to ease of disassembly)
- Design for durability (e.g. durability of the core skeleton of product with modules which can be replaced)
- Designing out waste in the production process
- Enabling a flow of information about disassembly, quality checking, remanufacture and testing to others in the supply chain

2.4.2 Innovative business models

The key features of innovative business models in a circular economy include:

- Changing ownership to performance based payments (e.g. tyre leasing, plant hire, etc.)
- Producers/suppliers retain ownership of vehicle to provide incentive to consider whole life costs and longevity of function at the design stage
- Warranties offered on refurbished vehicles and remanufactured parts and components

2.4.3 Reverse logistics

The key features of reverse logistics in a circular economy include:

[21] „Towards the Circular Economy', Ellen MacArthur Foundation, Vol. 1, p.28, 2012

- Better quality collection and treatment systems (e.g. sourcing the correct quantity and quality of core parts in the right geographical location). The handling, transportation and storage of CAN bus mechatronic cores is becoming an even more crucial one that that of purely mechanical cores[22]
- Centralised refurbishment and remanufacturing capability to achieve specialisation and economies of scale (already apparent in the remanufacturing sector where companies specialise in specific parts and components, e.g. transmissions, ECUs, etc.)

2.4.4 Enabling factors

A number of enabling factors are also important in developing a circular approach:

- Collaboration across supply chains is a crucial part of a successful circular economy. This is manifest in the way in which competitive advantage is currently gained in some parts of the automotive supply chain by not collaborating, e.g. in the area of reverse engineering, component replacement, and testing of mechatronic components. This leads to significant investment being required in establishing remanufacturing operations, particularly where electronic hardware and software systems are involved. Overcoming these commercial barriers and developing comprehensive shared data systems is a difficult issue to address. An example of where information sharing between producer and dismantler has been addressed, through the use of regulation, is the International Dismantling Information System[23]
- Industry standards and certification is also a significant issue. Overcoming consumer perceptions about the quality of the goods they are purchasing, leasing etc. is affected by the loose terminology used in the market. For example, it can be difficult for consumers to differentiate between companies claiming to supply refurbished parts and components and those supplying genuinely remanufactured parts and components. This issue is in the process of being partly addressed by the development of a British Standard for remanufacturing[24]
- Education and skills in remanufacturing and refurbishment is an important feature. This is relevant at all levels of employees. For example, the

[22] Sundin, E. And Dunback, O., „Reverse logistics challenges in remanufacturing of automotive mechatronic devices', Journal of remanufacturing, 2013, 3:2 - http://www.journalofremanufacturing.com/content/3/1/2

[23] An information sharing system between car producers and dismantlers, developed to meet legal obligations under the ELV Directive by supporting the depollution process – covers 1775 different models from 69 car brands - http://www.idis2.com

[24] BS 8887-220:2010 Design for manufacture, assembly, disassembly and end-of-life processing (MADE). The process of remanufacture. Specification

management skills and capabilities of business leaders and the increasing technical capabilities of operators

- Finance is also required to support research, development and deployment in areas such as initial product design, new business models and collection and remanufacturing of cores and dismantling/refurbishment of vehicles
- Supporting policy and regulation is required to provide a stable environment for investment. This could include:
  - Increasing landfill tax
  - Public procurement of remanufactured/refurbished parts and components (e.g. a study estimated that public bodies in the North East of England could save over £1m p.a. by procuring remanufactured vehicle parts instead on new[25])
  - Moving taxation from labour (a renewable resource) to material use (mostly non renewable and increasing supply pressures)
  - Customer and corporate responsibility regulation (e.g. in the areas of sourcing and end of life treatment routes for vehicle parts and components)

2.5 Supply chain overview and market size

Section 2.4 provides an indication of a „model' circular economy. To further illustrate this model it is useful to identify and define the different types of business involved in remanufacturing[26]:

- OEM Remanufacturers, which are typically the vehicle producers that remanufacture mainly their engines and gearboxes
- Tier One Remanufacturers, which are mainly the original manufacturers of original components
- Independent Remanufacturers, which are often privately owned and which remanufacture for the independent aftermarket but sometimes also for the OEM and Tier ones
- Local Rebuilders [Refurbishers], which are privately owned and perform rebuilding for the local market. They are often service workshops franchised by the Tier one

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[25] Centre for Remanufacturing and Reuse, „Public Procurement of remanufactured goods' 2011 - http://www.remanufacturing.org.uk/pdf/story/1p484.pdf

[26] „European Automotive Remanufacturing – Technical Trends and Market Development' (Ed. Fernand J. Weiland), p.134 (Paper by Fernand L. Weiland; FJW Consulting, „European Automotive Remanufacturing – Where is it Heading?')

Each of the above has differing ability to influence design, change business models and acquire cores. They also have different access to knowledge of the disassembly process, sub-component sourcing and testing equipment/procedures.

In addition to this, there are a significant number of service/repair garages that source reused, refurbished and remanufactured parts and components. They are also the source of core parts for refurbishment and remanufacturing operations. Finally, the ELV dismantlers are an important part of the supply chain, operating as core parts providers.

The current simplified supply chain is summarised in the figure 13, below.

	Supply chain position					
Automotive sector segment	*OEM Remanufacturer*	*Tier 1 Remanufacturer*	*Independent Remanufacturer*	*Local Rebuilder/ Refurbisher*	*Service/Repair garage*	*ELV Dismantler*
Passenger car / Light van	Not currently economically viable at vehicle level Some OEM remanufacture of parts/components for new vehicle production	Significant remanufacture at part/component level for aftermarket	Significant remanufacture at part/component level for aftermarket	Niche market in classic cars at vehicle level Significant refurbishment of parts/component level for aftermarket	User of remanufactured/ refurbished and reused parts and components Supplier of cores	Supplier of reused parts/components Supplier of cores
Truck and bus	Not currently economically viable at vehicle level No OEM remanufacture of parts/components for new vehicle production was identified	Significant remanufacture at part/component level for aftermarket	Activity in vehicle level remanufacture (e.g. fork-lift trucks) Significant remanufacture at part/component level	Activity in vehicle level refurbishment (e.g. refuse collection vehicles)	User of remanufactured/ refurbished and reused parts and components Supplier of cores	Supplier of reused parts/components Supplier of cores
Heavy plant	Significant remanufacture of parts and components for use in new vehicle production	Remanufacture at part/component level for new vehicle production and aftermarket	Significant remanufacture at part/component level for aftermarket	Activity in vehicle level refurbishment (e.g. earth moving equipment)	User of remanufactured/ refurbished and reused parts and components Supplier of cores	Supplier of reused parts/components Supplier of cores
Supporting activities	*Finance and risk management*					
	Reverse logistics (e.g. core brokers)					

Figure 13 - Overview of automotive supply chain and current state of reuse, refurbishment and remanufacture at vehicle and part/component level

The above figure provides a framework for subsequent discussion about areas of opportunity, detailed in section seven.

Of the estimated 22 million remanufactured/rebuild units produced every year in Europe (for the car and light van market) the market share (volume and value) is split between the above company types as follows:

Company type	Market share (22m units)	
	Volume	Value
Tier One Remanufacturers	42%	38%
Independent Remanufacturers/Rebuilders	52%	48%
OEM Remanufacturers	6%	14%

Figure 14 - Estimated breakdown of reman/rebuild units in Europe by business type[27]

The value and volume market shares are different due to the average OEM remanufactured components (engines, gearboxes etc.) having a value of around five to eight times higher than average.

Rough estimates of the number of remanufactured and rebuild units supplied to the car and light van market (in the EU) are shown figure 15, below.

European Automotive Remanufacturing (units)	Annual Volume	
	Reman units	Rebuild units
Starters, Alternators, Pulley & small motors	5,900,000	400,000
Manual Steering, Power Steering, Hydraulic pumps, Oil pumps and Water pumps	790,000	
Gasoline & Diesel injection components, Injectors and Ignition	1,825,000	4,675,000
Electronic Units, Instrument Clusters & Controllers	700,000	
Combustions Engines, Cylinder Heads, Engine Components and Turbochargers	980,000	890,000
Brake Components, Calipers, CV driveshafts	3,850,000	
Transmissions, Gearboxes and Clutches	1,969,000	49,000
Air Condition Components	210,000	75,000
Total	**16,224,000**	**6,089,000**

Figure 15 - Aftermarket replacement demand supplied by remanufactured/rebuild units in the EU[28]

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27 „European Automotive Remanufacturing – Technical Trends and Market Development' (Ed. Fernand J. Weiland), p.158 (Paper by Fernand L. Weiland; FJW Consulting, „European Automotive Remanufacturing – Where is it Heading?')

28 „European Automotive Remanufacturing – Technical Trends and Market Development' (Ed. Fernand J. Weiland), p.157 (Paper by Fernand L. Weiland; FJW Consulting, „European Automotive Remanufacturing – Where is it Heading?')

The publication by Weiland identifies that some remanufactured and rebuild components are at a mature state (e.g. starters, alternators etc., where remanufactured and rebuild units supply nearly 90% of the aftermarket). Other areas are at an earlier stage of development, such as ECUs, etc, and therefore offer greater growth potential. The overall EU supply of ECUs, Instrument Clusters and Controllers is 14% of the aftermarket. It is estimated that this figure is around 50% in the US, suggesting room for growth. Specific components are highlighted as having the most potential for remanufacture:

- Electronic control units (EU aftermarket supply of reman/rebuild is 300,000 of 2.5m total units (12%)), with most attractive units for remanufacture being:
  - Engine management for petrol/gasoline fuel injection
  - Engine management for diesel fuel injection
  - Chassis control for brakes and steering
  - Automatic transmissions
- Electronic infotainment units (EU aftermarket supply of reman/rebuild is 400,000 of 2.4m total units (17%)), with most attractive units for remanufacture being:
  - GPS navigation
  - Audio (DVD, Radio etc.)
  - Instrument clusters

However, this market requires high investment for non-OEM remanufacturers in reverse engineering the electronic hardware and software and creating test-rigs and programmes. This is indicative of a growing issue which will be increasingly faced by remanufacturers in future as components move from mechanical/electro-mechanical to mechatronic, as detailed earlier.

2.6 Other country responses to a circular approach

The previous discussion on remanufacturing and refurbishment has so far focused on the European market developments. Of course the remanufacturing sector is global in nature and there are several notable countries where specific policies and development measures have been introduced.

Remanufacturing has been a feature of the 10th, 11th and 12th Five Year Plans of China (in 2000, 2005 and 2011, respectively). In 2004, remanufacturing was promoted as a key area in the State Circular Economy Projects. In 2010, the National Development and Reform Commission and 11 ministries of China jointly issued the document „Opinions on promoting Remanufacturing Industry'. This provided guidance on factors such as: technology, management, support systems and policy safeguards, which affect the development of remanufacturing as well as highlighting the remanufacturing industry as a new growth point of China's economy. In Beijing there is the National Key Laboratory for Remanufacturing which is thought to focus on military applications[29].

An example of investment in automotive remanufacture in China by an indigenous company is Mingjie, which, working with the German Fraunhoffer-Gessellschaft Bayreuth, is developing a facility in Guangdong Province to remanufacture turbochargers, engines and starters[30].

In the United States there is a well developed remanufacturing sector, thought to employ nearly 500,000 people. Several states have proactive procurement policies in place to promote the purchase of remanufactured goods. In 2000, New York State introduced legislation to introduce a tax credit for recycling and remanufacturing. The US based Centre for Remanufacturing (based at the Rochester Institute of Technology) offers R&D support, structural and material analysis, product design advice, training and policy advice related to remanufacturing[31].

A new „Advanced Remanufacturing & Technology Centre' (ARTC) is due to be launched in Singapore. It will be managed by the Singapore Institute of Manufacturing Technology (SIMTech) which is a research institute of the Agency for Science, Technology and Research. The ARTC will be situated at CleanTech II, a new development located on the campus of Nanyang Technological University. Operations at the Centre are planned to start at the end of 2013 with significant funding support from the Singapore Economic Development Board. Its technology focus is on repair and restoration, surface modification & product verification. The Industrial membership interest includes; Rolls-Royce, Boeing and Siemens[32].

Section seven of this report discusses the areas of potential longer term opportunity arising from the above trends and developments.

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[29] Information supplied via personal communication with Dr Winifred Ijomah, University of Strathclyde

[30] „From Recycling to Remanufacturing – a success story in China', Presentation at the Remanufacturing World Summit, Bayreuth, 2012 (Wu and Koehler)

[31] http://www.reman.rit.edu

[32] www.artc.a-star.edu.sg

3. Current situation in Scotland

This section considers the current situation in Scotland, focusing mainly on how ELV dismantlers and shredders are responding now, and in the short term, to the 2015 ELV Directive targets.

Firstly, a summary of the current ELV dismantling and shredding sector is provided, including an overview of the relevant legislation and sector structure. The remainder of the section details the results of an in-depth interview programme that obtained feedback from the majority of Scottish based ATFs on their current practices, processes and future plans.

3.1 Relevant regulations and industry structure

The UK Government has introduced a number of regulations to transpose the EU ELV Directive into UK law:

- The End-of-Life Vehicles Regulations 2003
- The End-of-Life Vehicle (Producer Responsibility) Regulations 2005
- The End-of-Life Vehicles (Amendment) Regulations 2010
- The End-of-Life Vehicles (Producer Responsibility) (Amendment) Regulations 2010

The 2003 and 2005 regulations are complimentary and the 2010 regulations make largely technical amendments to the 2003 and 2005 regulations[33].

The 2005 regulations introduced two targets for reuse and recycling of ELVs. These are aligned with ELV Directive targets and apply at a UK level:

- Regulation 18(1) of the 2005 regulations sets a target of 80% reuse and recycling and 85% reuse and recovery during 2006 and in subsequent years
- Regulation 18(2) of the 2005 regulations sets a target of 85% reuse and recycling and 95% reuse and recovery during 2015 and in subsequent years

These targets apply to producers through their collection networks and to ATFs where vehicles are treated independent of any agreement with producers.

In addition to the above UK regulations, Scotland has introduced the „End-of-life Vehicles (Storage and Treatment) (Scotland) 2003' which relate to licence conditions for the storage and treatment of ELVs in Scotland.

[33] „The End of Life Vehicle Regulations 2003, 2005 and 2010', Government Guidance Notes, BIS, July 2010

The system developed under the UK regulations provides “free take back” under producer responsibility (2005 regulations). The vehicle manufacturers and importers use two companies to contract with a compliance scheme. These companies award contracts on behalf of the manufacturer to chosen Authorised Treatment Facilities. The ATF then provides a “free take back” service for the manufacturers as directed by the compliance scheme and reports back on recycling and recovery performance.

Over 50 ATFs in Scotland are contracted to vehicle manufacturers through the two compliance schemes. Collectively, these ATFs treated over 70,000 ELVs in 2011 and demonstrated the 85% reuse and recovery target was met on them. There is some cross over between ownership of shredders in Scotland and affiliation to one or other of the compliance schemes (in some cases the Directors of shredder companies are also Directors of a compliance scheme)[34].

Authorised Treatment Facilities

The ELV industry in Scotland is characterised by a large number of vehicle dismantlers and a small number of shredders. Dismantlers can be specialist businesses focusing predominately on ELVs or they can be part of larger metal trading businesses. They generate revenue through the removal of parts and components for reuse, refurbishment and remanufacture and also through the sale of the depolluted and dismantled hulks to shredder operations. Some dismantlers offer recovery and collection services for ELVs in their local area and some also offer fitting services for reused parts and components.

Shredders mechanically reduce the ELV hulks to small pieces and automated equipment sorts this into different metallic fractions. In addition to treating an estimated 100,000 ELVs annually[35] the shredders also process other end of life products, such as WEEE, in a continuous process. This means that the output material is made up of more than just materials contained within ELVs.

To operate as an ATF in Scotland the business has to be licensed by SEPA. Currently there are 137 ATF sites in Scotland. There are also believed to be a significant number of unauthorised operators working outside of the licensing system. These unauthorised operators seek to purchase ELVs and profit through their sale as scrap metal without carrying out the required depollution steps.

The waste management licence requires a site infrastructure that contains an area of impermeable surfaces (with sealed drainage system if in an open space). All non-depolluted ELVs must be stored on this surface and any depollution activity must be carried out on this surface. The licence attracts an annual fee.

[34] Data and information provided via personal communication with BIS, November 2012

[35] Based on Certificates of Destruction data provided by the Department of Business, Innovation & Skills (2009 – 110,677, 2010 – 93,112 and 2011 – 96,717 CoDs issued by ATFs in Scotland)

Depollution Process

The requirements of depollution are detailed in statutory guidance[36]. This guidance, from the lead government department, BIS, states the required levels of depollution and the activities and processes that have to be carried out to achieve “full depollution”. This includes removal of all fuels and fluids, batteries, explosive components and mercury components.

The guidance does not prescribe the manner in which the process achieves the depollution or the equipment to be used; this is left to the operator to choose.

Once fully depolluted, the ELV can be stored for future removal and sale of used spare parts.

At the stage where the ELV is no longer required for parts, the total hulk, including all parts not removed for re-sale, is sold to a scrap metal merchant or directly to a shredder operator for recycling.

3.2 Reprocessing infrastructure and capacity

3.2.1 Geographical spread of ATFs

The geographical location of the 137 ATFs in Scotland is shown in the map at figure 16.

36 http://www.bis.gov.uk/assets/biscore/business-sectors/docs/d/11-528-depolluting-end-of-life-vehicles-guidance.pdf

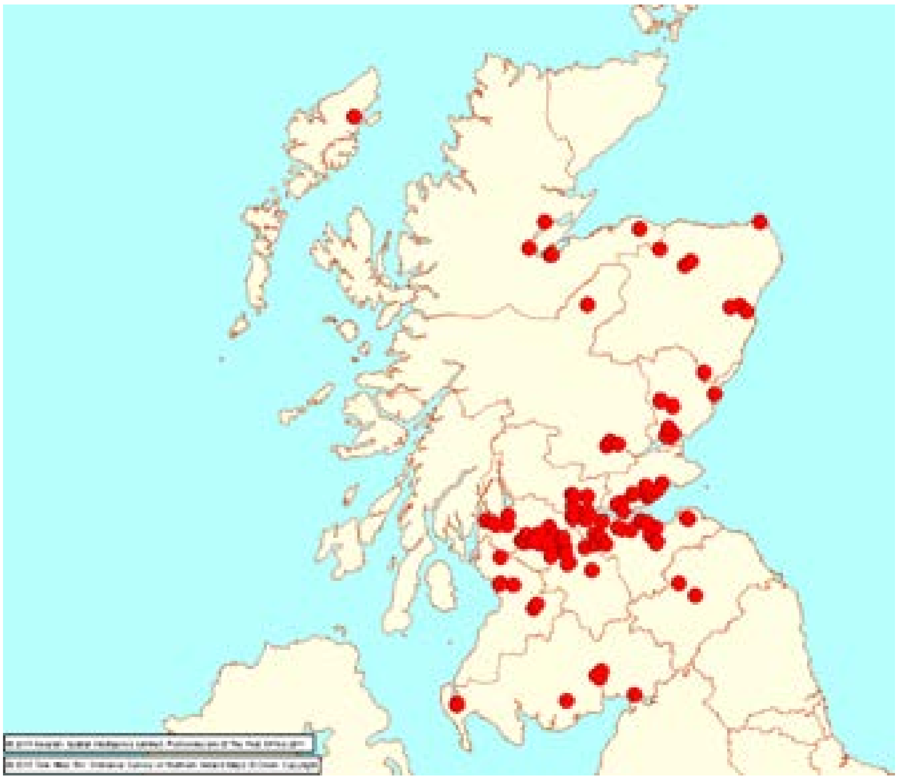

Figure 16 - Map of Scottish-based ATFs

The above map shows the concentration of ATFs around the main population areas of Scotland, as would be expected. There are an additional two ATFs located in the Shetland Isles.

The original database of ATFs, accessed via the SEPA website, had 145 entries. During the research process seven duplicate entries were identified resulting in a total population of 137. Of this:

- 72 dismantlers were interviewed (via the structured survey) - 53%
- 4 large shredders were interviewed (face-to-face or in-depth telephone interview) – 3% of all ATFs but these are the four largest shredders in Scotland
- 24 refused to participate (mainly stating lack of time) – 18%
- 4 stated they no longer processed ELV – 3%
- 33 were contacted on at least 5 occasions but were unavailable – 24%

Feedback was, therefore, obtained from 56% of ATFs (by number).

3.2.2 Number of operational sites

The majority of ATFs in Scotland are single site operations (90% of the survey response) as shown in the figure below.

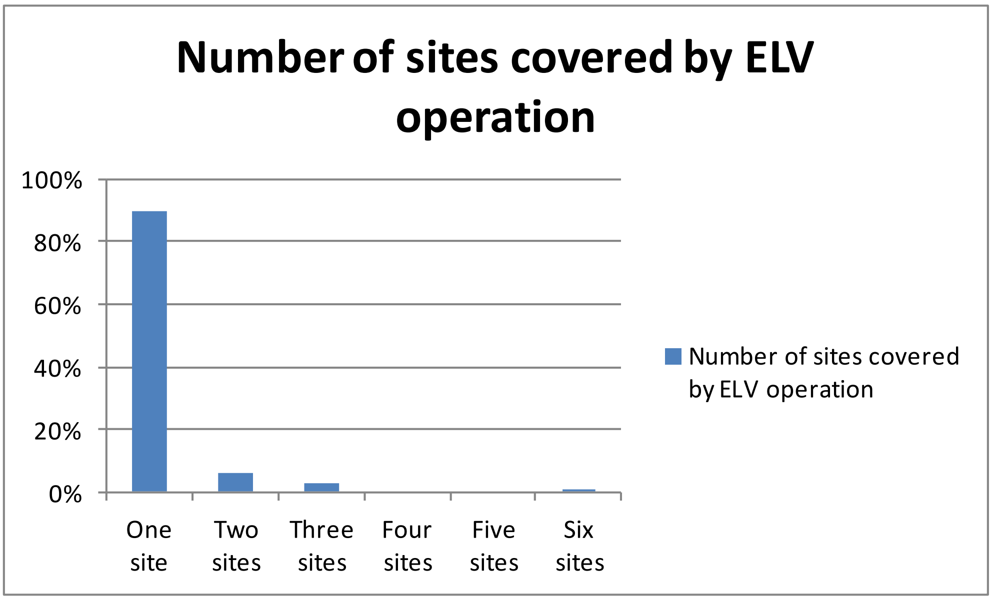

Figure 17 - Number of sites covered by ELV operations (72 responses)

Figure 17 shows the structure of the industry is predominately based on single site operations.

3.2.3 Employment in ATFs

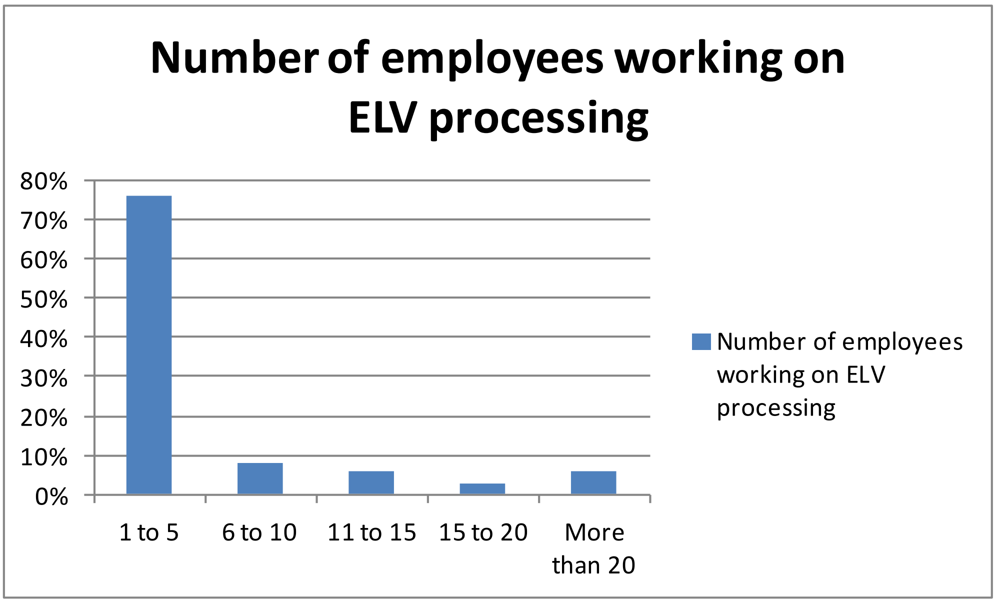

Figure 18 - Number of employees working on ELV processing (71 responses)

Around three quarters of ATFs have between 1 and 5 employees. A total of 370 employees were found to be working on ELVs from the 71 respondents who provided data. On average each ELV operation employed 5 people.

3.2.4 ELVs processed at ATFs and capacities

A total of 65 of the 72 survey respondents provided information on the number of ELVs processed in 2011. In total, the sample estimated that 68,355 ELVs were processed in that year, an average of just over 1,000 ELVs per ATF (with the responses ranging from as low as 10 to as high as 9,000). Comparing this to the estimated 96,717 ELVs processed by ATFs in 2011 suggests that the survey respondents accounted for 70% of ELVs treated in Scotland in that year. This does not include the ELVs processed by the seven respondents who answered „don't know' to this question. A number of ELVs will also have been processed directly by the four shredders interviewed (and this proportion of ELVs is not included in the 70% identified above).

A total of 65 of the 72 survey respondents provided data on the capacity of their ELV operations. On average, ATFs are working at 63% of capacity (ranging from 3% to 100%). Comparing capacities to their 2011 estimates of numbers of ELVs processed suggests that the 65 ATFs responding to this question could deal with an additional 23,770 ELVs with current operations.

3.2.5 ELV Practices and Processes

A total of 68 of the 72 respondents stated that they dismantled ELVs on site. Of those that stated they did not dismantle, one had been taken over in 2011 and was currently changing their approach to ELVs and the remaining three uplifted and passed on down the supply chain.

This section should be read in the context of the legal requirement to undertake specified depollution processes, including the removal of[37]:

- Any batteries.
- The liquefied gas tank.
- All potentially explosive components, including air bags.
- All fuel, motor oil, transmission oil, gearbox oil, hydraulic oil, cooling liquids, antifreeze, brake fluids, air conditioning system fluids and any other fluid contained in the vehicle (excluding any fluid which is necessarily retained for the re-use of the part concerned).
- So far as is feasible, all components identified as containing mercury.

In addition to the above specific legal requirements relating to the ELV directive, the recovery of ozone depleting substances (i.e. gases such as CFCs) from air conditioning

37 http://www.sepa.org.uk/waste/waste_regulation/producer_responsibility/end_of_life_vehicles/end_of_life_vehicles_faqs.aspx

units is also a legal requirement under „The Environmental Protection (Controls on Ozone-Depleting Substances) Regulations 2011' with the qualifications of persons carrying out the relevant work defined in „The Ozone Depleting Substances (Qualification) Regulations 2009'. Advice from industry stakeholders indicates that only specialist air conditioning gas recovery equipment is suitable to comply with these regulations.

<u>Current processing equipment</u>

The 68 that stated they do dismantle were asked to identify the processing equipment they currently had available at the ELV site. Figure 19, shows the spread of responses:

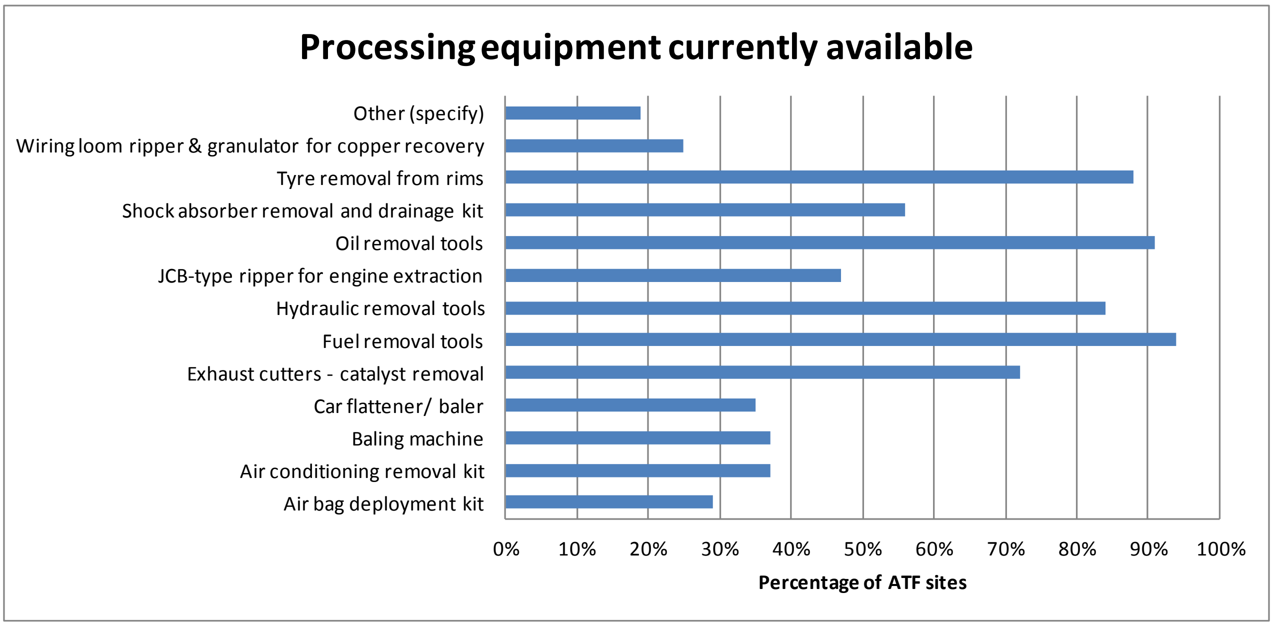

Figure 19 - Processing equipment currently available at ELV sites (68 responses)

The use of air conditioning removal kit is low given that the removal of air conditioning gases is a legal requirement (and can only be properly carried out using specialist equipment). This suggests that even within authorised ATFs the depollution processes do not appear to be fully compliant with legislation out at some sites. It may be that there is a lack of awareness of the need to remove air conditioning gases as this is mandated by different legislation, as detailed on the previous page. This may be an area for further development to increase awareness of the legal requirements relating to the removal of air conditioning gases in particular and overall depollution in general. Such awareness raising could include advice on the types of equipment and training necessary to comply with legislation.

The „other' equipment specified by respondents included:

- Hire in a baler as and when we need it
- Normal tools we use for repairing cars and replacing parts

- Special decontamination unit
- Jaws of life (hydraulic cutting/spreading tool)
- Holmatro hydraulic cutting tool
- Autodrain Equipment
- Run of the mill processing equipment
- Granulators
- Cable stripper
- De-pollution and removal tools

The equipment used is common and is developed and sold by both UK and European manufacturers. Feedback from industry is that there is no equipment or practices used in Europe that are not known to UK industry. Latest developments are promoted and shared through specialist industry websites[38] and trade shows.

Manual removal of vehicle parts

Figure 20 summarises current practice in manual removal by part and/or material type.

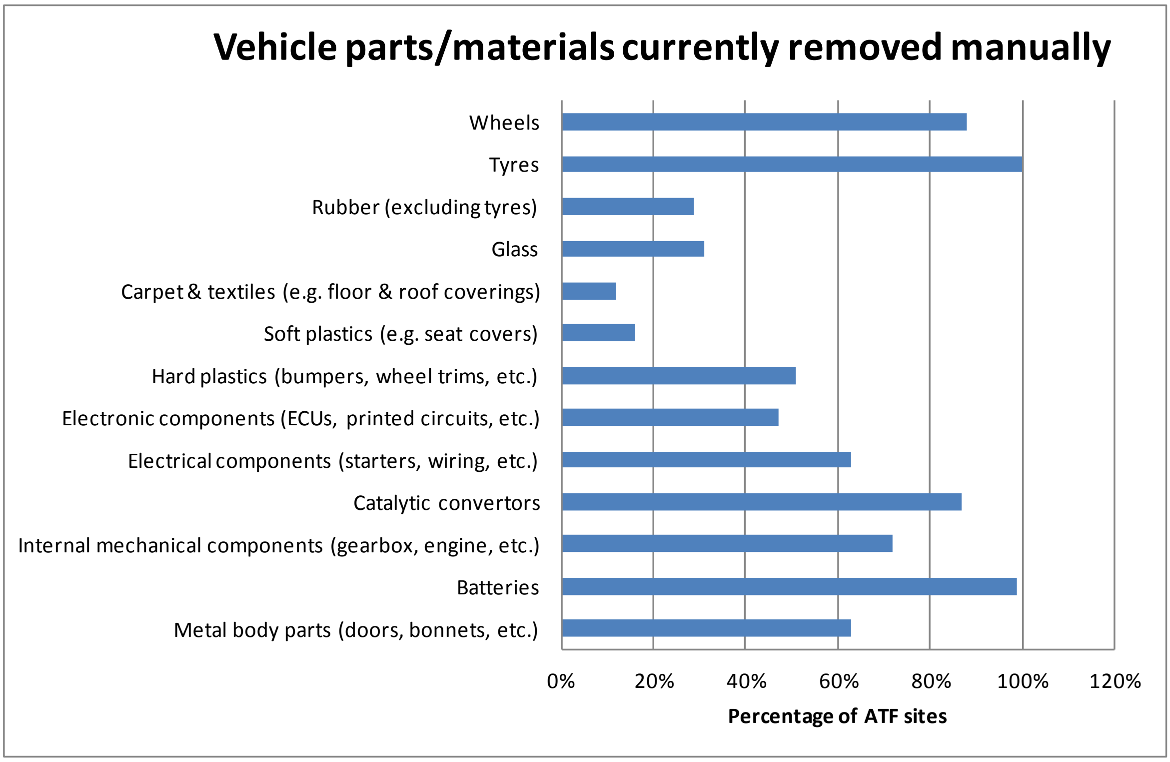

Figure 20 - Vehicle parts/materials currently removed manually (68 responses)

[38] For example, www.atfprofessional.co.uk

The manual removal referred to in the above figure includes where parts are manually removed from some or all ELVs. The breakdown between the two is shown in figure 21.

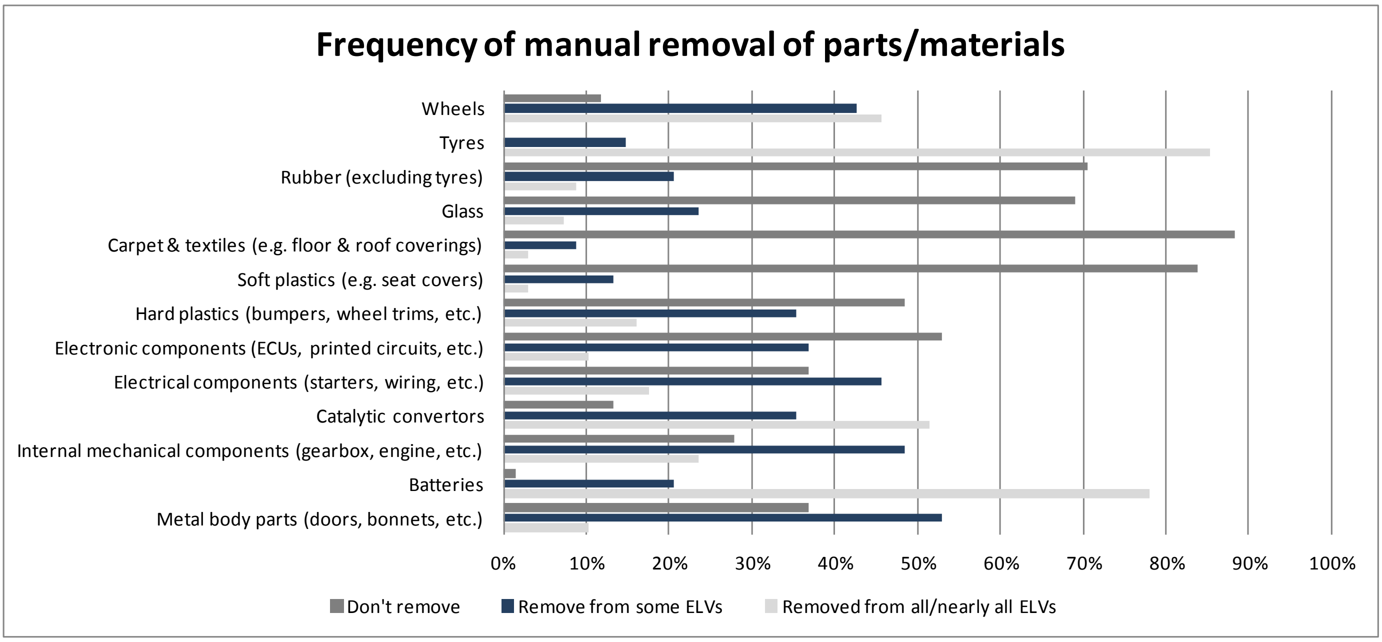

Figure 21 - Frequency of manual removal of parts/materials of ELVs (68 responses)

Industry stakeholders expressed a level of surprise that the survey results suggested a significant amount of batteries and catalytic convertors were not removed, as these parts have value to a reprocessor and are a mandatory part of the depollution process.

<u>Onward use of manually removed parts/ materials</u>

Those respondents who stated that they manually removed parts/materials from ELVs were asked to identify whether this was carried out for reuse, recycling or energy recovery. Figure 22 summarises the response.

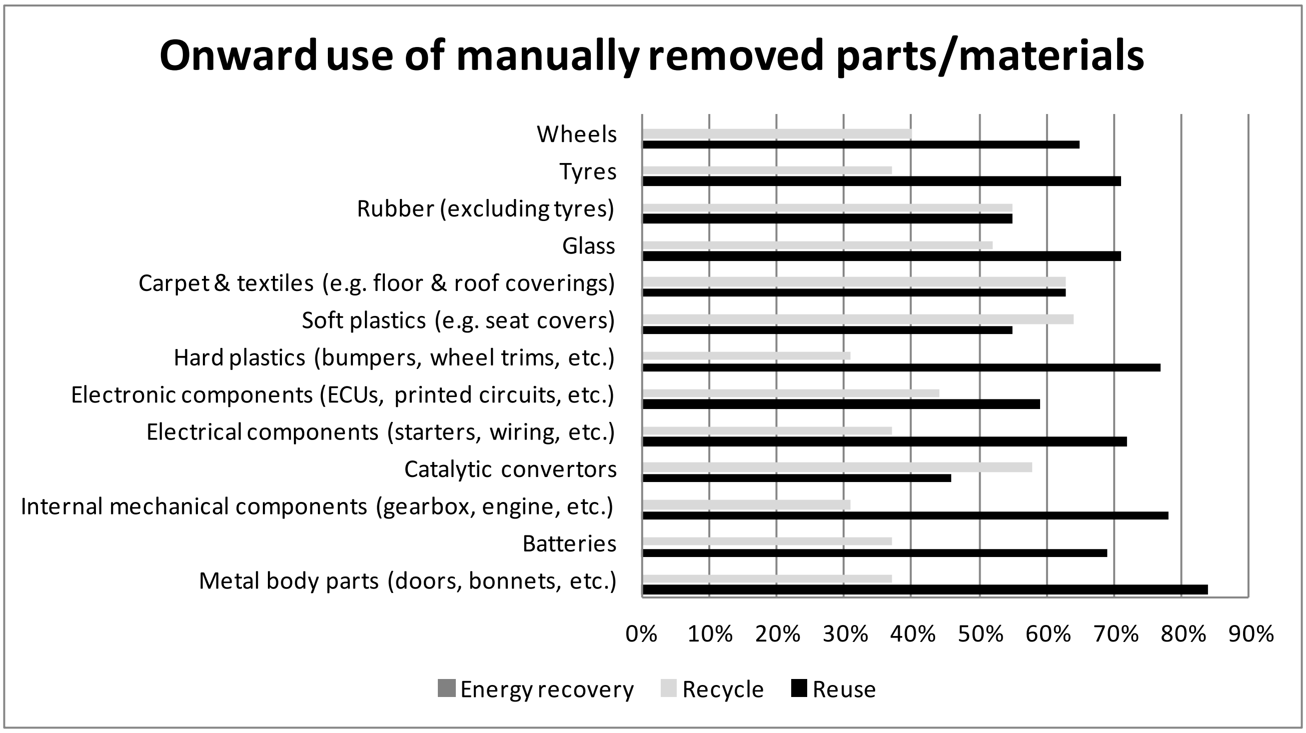

Figure 22 - Onward use of manually removed parts/materials (responses from those who manually remove - not the total sample)

Note that total percentages can exceed 100 in circumstances where ATFs both reuse and recycle parts/materials. Further feedback from the material reprocessing sector suggests that some materials are used for energy recovery, for example tyres used to fuel cement kilns (even though no ATFs stated this was the case). This could be due to an understandable lack of knowledge by the ATF on what the reprocessor uses certain parts and materials for. The markets for the parts and materials are discussed in section six.

3.3 Material flows

This section describes the geographical location of the customers, to which parts/materials are sold by ATFs. Clearly, sales could be made to intermediaries and the part/material could then be sold again to different geographical locations. This analysis refers only to the first transaction between ATFs and their customers.

3.3.1 Location of customers for parts/ materials sold by dismantlers

Respondents were asked to identify the approximate percentage of sales of the part/materials that were removed manually. The response options were „Scotland', 'Rest of UK' and „Exported'. The responses were then aggregated to obtain an estimate of the average geographical location of onward sales. This calculation weighted the individual response by the number of ELVs treated in 2011 (which assumes that each ATF that manually removes the respective part/material does so at the same rate). The results are summarised in figure 23, below.

Part/material	Location of customers buying parts/materials removed		
	Scotland	Rest of UK	Export
Metal body parts	82.0%	18.0%	0.0%
Internal mechanical components	79.6%	20.3%	0.1%
Batteries	79.8%	20.2%	0.0%
Catalytic convertors	73.5%	26.5%	0.0%
Electrical components	92.5%	7.5%	0.0%
Electronic components	92.6%	7.4%	0.0%
Hard plastics	91.6%	8.4%	0.0%
Soft plastics	100.0%	0.0%	0.0%
Carpet and textiles	100.0%	0.0%	0.0%
Glass	99.8%	0.2%	0.0%
Rubber (excl. tyres)	92.0%	8.0%	0.0%
Tyres	94.1%	5.9%	0.0%
Wheels	91.1%	8.9%	0.0%

Figure 23 - Location of customers, by part/material manually removed

It should be noted that the above data regarding location of customers buying materials and parts refers only to the first onward sale by the ATF. Further investigation, of the companies named by the ATFs, indicates that a high proportion of these are collectors and aggregators who then sell on to others, frequently outside Scotland, for reprocessing.

It should also be noted that figure 23, above, refers to the first onward sale of parts and materials actually removed from the ELVs not those present on the vehicle itself. For example, 82% of metal body parts are sold to customers in Scotland but this only refers to those metal body parts which are removed prior to shredding.

After depollution and subsequent manual removal of parts and materials, the ELV carcasses are then processed mechanically to retrieve metals. Figure 24, below, shows the geographic location of the customers who buy these carcasses from ATFs.

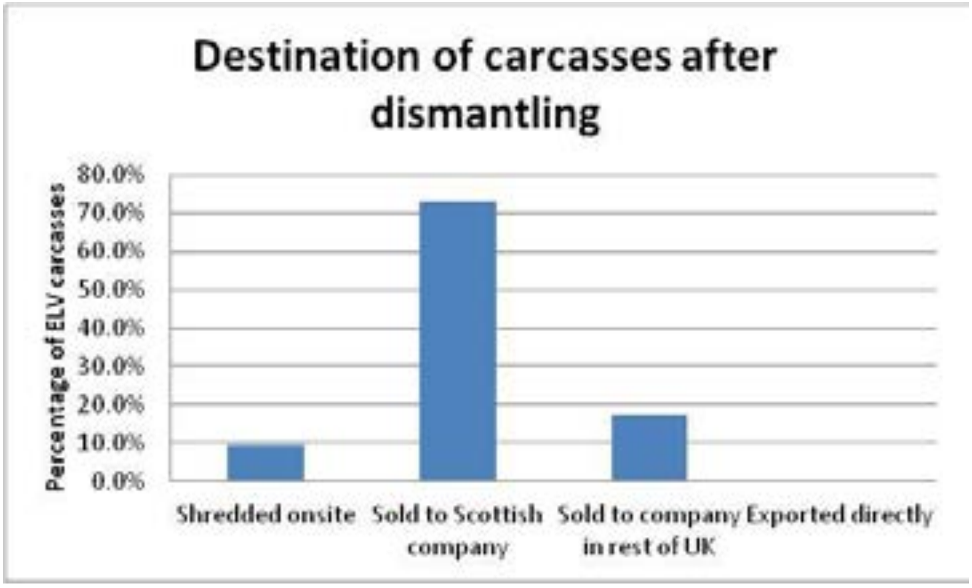

Figure 24 - Destination of ELV carcasses after depollution and dismantling (60 responses)

Data in figure 24 are from the structured survey and, therefore, do not include the four largest shredders in Scotland (who were interviewed separately). Six respondents to the structured survey indicated that they had onsite shredding capacity. It is estimated that these six companies shredded 6,400 ELVs in 2011.

3.3.2 Arisings and treatment of ASR from shredders

On the basis that the shredding/fragmentising industry in Scotland, and beyond, is going to be one of the key sectors in a successful shift from 85% to 95% recycling/recovery, the four main shredder operations were interviewed to review current practice in terms of volumes handled and amounts landfilled. The outcome of that feedback is summarised below, showing estimates of annual input of ELV materials, amounts recycled and ASR landfilled.

Shredder (conf. reference no.)	Annual Input of ELV Materials (tonnes)	Annual Amount Recycled (tonnes)	Annual ASR Amount Landfilled (tonnes)	Comment
1	30,000	24,000	6,000	Operator's calculated annual figure. Of the 6,000 they feel further diversion can be achieved. Progress possible in more metal recovery (37% of total); Plastics (17%); Rubber (9%); Foams (6.5%), and; Wood (4.5%). Trials of ASR composition have been carried out.
2	20,000	15,000	5,000	This operator indicates 55% of tonnage from ELVs and 45% from other scrap, but that will vary dependent on the construction industry. The majority of the other scrap is sheared or aggregated in bulk separately from the ELV waste. Recent investment in end of line metal recovery (type of equipment is confidential to the shredder).
3	19,000	15,100	3,900	This operator has substantial other tonnage going through the shredder, but ELV figures are kept separately and these provided as up to date figures.
4	28,700	23,250	5,450	These figures taken from 2010 SEPA data.
Total	**97,700**	**77,350**	**20,350**	This figure is ELV based. See **Note** below.

Figure 25 - Estimated ELV material flow through four large Scottish shredders

Note: The above data are from company interviews and/or SEPA 2010 returns, dependent on the degree of accuracy assumed during the survey. The figures focus on waste from

ELVs; but it should be noted that the total input of all material delivered to these sites and processed by them seems to be greater than ELVs alone. It is estimated that total shredder residue (SR) arisings (ELV, WEEE, etc.) in Scotland are around 60,000 tonnes per annum.

3.4 ELV resource value

Typical values at each stage of the chain include:

- Consumers typically sell their car to a recycler for around £150
- The recycler/dismantler extracts what value they can from the vehicle. This is estimated at £100 per ELV, on average, although lower and upper ranges can vary considerably. For example, the same part for a Ford Fiesta will be cheaper than that for a Mazda MX5
    - Approximate values (typically used in the dismantling sector) for parts and components sold for reuse are:
        - 20% of the cost of a motor manufacturers original equipment price, e.g. bought from Ford main dealer
        - 50% of cost against a new part manufactured independent of original equipment manufacturers
- Dismantlers then sell the depolluted hulk onto a shredder at a price ranging from £125 - £175/tonne
- Shredder operators can currently expect to achieve around £260 per tonne for ferrous metals and an average of £1,000 per tonne for non-ferrous metals (average across a range of non-ferrous materials)

More detail on the values used for the model projections part of this project is provided in section eight.

3.5 Barriers to increased recycling/recovery and value

Some of the key barriers to increased recycling/recovery are described below.

3.5.1 Competition from unauthorised/non-compliant operators restricting investment

There are two linked issues which contribute to this barrier. Firstly, there is the competition from unauthorised operators who do not have the appropriate waste management licences and are not authorised to issue Certificates of Destruction (COD). Secondly, there is competition from authorised operators who do have the necessary waste management licences but do not fully comply with the mandatory depollution processes.

The COD is a key element of the ELV Directive. It is issued to the last owner of the ELV as a proof that the vehicle has been properly treated by an ATF. The document is proof that the ELV has been deregistered by the vehicle licensing authority (DVLA). It is also the mechanism by which the recycling and recovery performance is measured.

Feedback from the dismantling sector highlights their belief that the number of CODs issued is significantly below the true number of ELVs entering the waste stream. Current figures for COD's issued in the UK are in the region of 1,200,000 (for 2010). In addition to this there were over 290,000 second-hand car exports in the same year[39]. Representatives of the dismantling sector estimate that the number of ELVs that arise per annum in UK is around 2,000,000.

The issuing of a COD can only be carried out by ATF with a waste management licence issued by the regulator. It is, however, possible for the last owner to inform the DVLA in writing, via form V5C, that the ELV has been scrapped. The DVLA then acknowledge that they have processed the V5C form. The DVLA does not appear to systematically cross-check its database for evidence of a COD being issued against the V5C forms received. In addition, there is no requirement on the V5C form for the last owner to confirm they been issued with a COD. The form does request details of the motor trader that ownership is being transferred to but feedback from dismantling industry representatives suggests that this is not systematically cross-checked to confirm a COD has been issued.

Cross-checking the last owners V5C form against the COD database would make it far harder for unauthorised operators to obtain scrap vehicles. This would, of course, require a change at a UK level based on the existing deregistration system (and potentially penalties or incentives for last owners connected to the successful receipt of a COD). The COD system issue is thought to occur in other European countries (to varying degrees).

The unauthorised operator is unregulated, potentially operates using methods which do not protect the environment and has a significant financial advantage i.e. no costs for permit, yard infrastructure, regulation, reporting, or in many cases VAT (although it could be the case that some businesses may not be a registered ATF but still pay VAT). In addition to this, there is the issue of authorised operators who do not comply fully with treatment standards (e.g. they may not fully depollute the ELV prior to shredding) which also gives them a cost advantage over those ATFs which carry out a fully compliant depollution process. In the latter situation a COD can still be issued so the opportunity to overcome this would rely more on increasing awareness of the legally required depollution process complimented with monitoring and enforcement by the regulator.

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[39] Data for the number of CODs issued in 2010 and the number of second-hand car exports in the same year were supplied via personal communication from BIS, November 2012

3.5.2 Lack of market pull for non-metallic parts/materials

ELV dismantlers are, by definition, driven by recycling. They respond to market demand for different parts/materials where there is an economic case to do so. Current market conditions mean that the natural focus of activity is on the recycling of metal. The more the metal can be segregated into different types, the higher the value that can be achieved. There is currently little market incentive to remove non-metallic materials unless the prices paid for the material are greater than the value paid by the shredder that purchases the carcass (around £125 - £175 per tonne).

3.5.3 Perceived quality of reused parts

The industry in the UK has, over the last three years, sought to have a quality specification for reused parts and components. The objective of this would be to increase the perceived quality of these parts and reduce the risk for consumers.

The proposed route was to create a Publicly Available Specification (PAS). A PAS is a consensus driven framework under which goods and services can be supplied to a consistent minimum quality standard (this process is less onerous than a full quality standard but is still an instrument valued by the market). The aim of the PAS would be to provide an audit trial for the parts through its various processes i.e. details of donor vehicle testing (visual or mechanical), despatch process etc.

This PAS would then provide the purchaser (vehicle repair/bodyshops/motoring public) with an assurance that the company supplying the part has a management system in place to monitor the process and, therefore, gain confidence in the supply. The PAS would likely include a minimum guarantee that would need to be offered on reused parts and components.

The industry was unable to raise the necessary funding to create and gain accreditation for the PAS. The associated cost was in the area of £65,000 for the development of the PAS. In addition to this, industry feedback suggests that the cost of establishing a system to comply with a PAS would be around £2,000 to £5,000 per ATF.

3.6 Options identified by ATFs to add value

Survey respondents were asked if there were things that could be done in Scotland or the UK to increase the value of recovered materials after processing. Figure 26, below, summarises the responses:

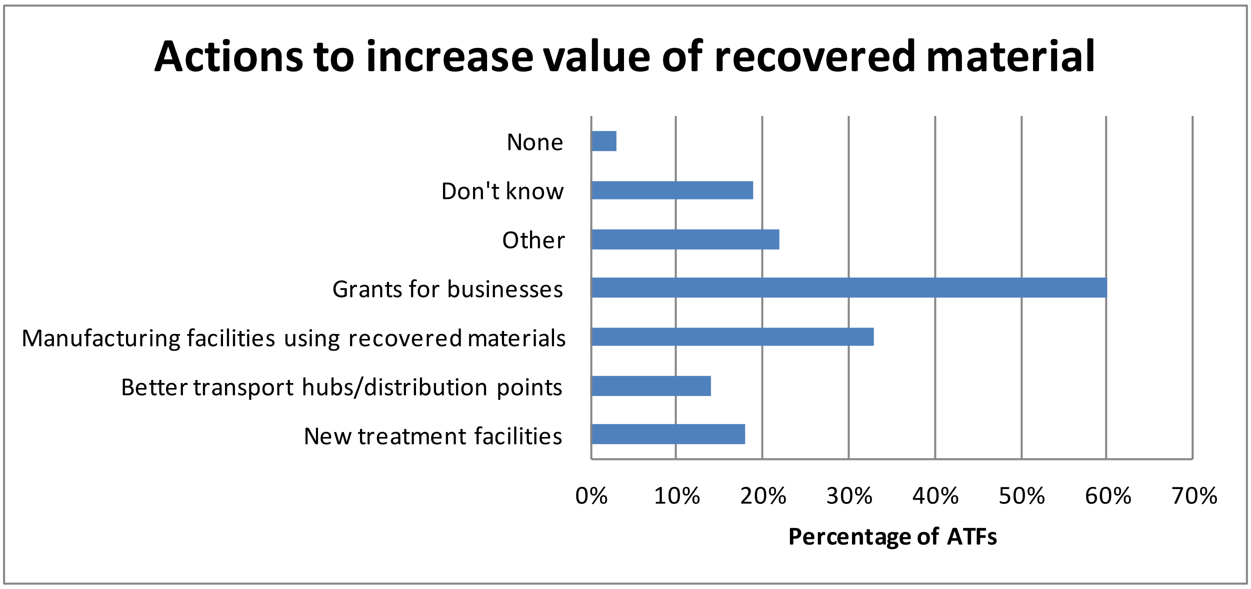

Figure 26 - Potential actions to increase value of recovered material in Scotland/UK (72 responses)

Of those respondents who selected „other' the following actions were proposed:

- More info on sites in Scotland that process parts and recycle materials
- More support from manufacturers on disposal of ELVs
- Recycling must be cost effective. Government has to be more supportive
- Price for scrap varies too much
- Make materials interchangeable as the materials are cheaper to buy from abroad
- Increase end markets
- Government allowances for smaller companies; by this I mean companies with 1 or 2 employees. The government think of small companies as having 200 employees not 2
- Stamp out illegal yards that operate where people don't pay taxes and can undercut us
- More Government financial support for recyclers
- A lot more government support than is currently offered
- Scotland needs to have major recyclers here, costs too much to send materials down south
- Stop speculators
- Consistent equal treatment. If we lived 2 miles away we would get grants for machinery but here we don't. It's a lottery situation with grants
- It's all too late for the industry now
- Too late, the government has done all the damage

- Outlets to get money for tyres rather than us having to pay for them to be disposed of. We have to pay 60p or 70p for a company to take these from us

There are a wide variety of responses. The common themes include more financial (and other) support from Government, the development of end markets and action against unauthorised operators.

3.7 Future plans of ATFs

3.7.1 Expectations about achieving the 2015 95% target

ATFs were asked if they expected to achieve the 95% recycling/recovery target by 2015. Figure 27, below, shows the responses.

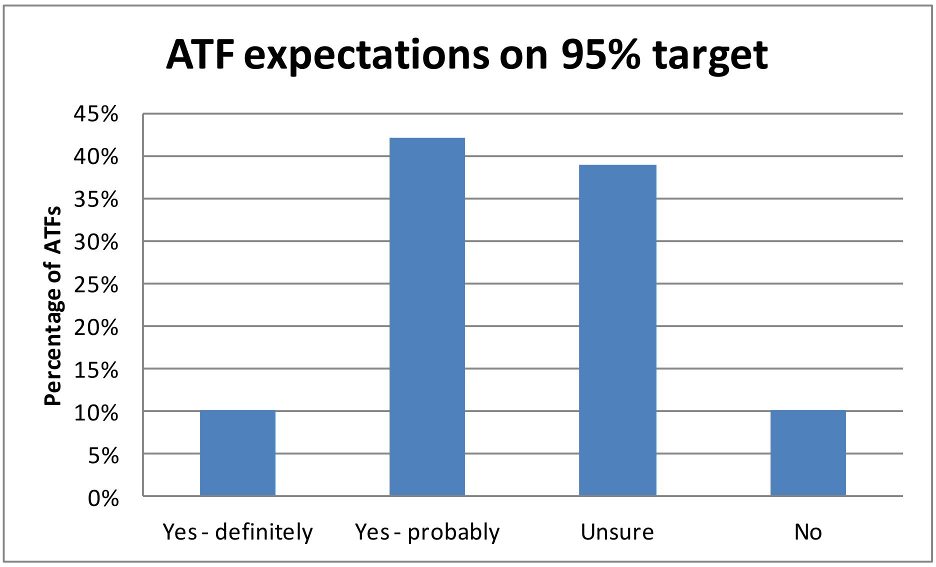

Figure 27 - Expectations of ATFs about their ability to achieve the 2015 95% target (72 responses)

The response shows a cautious optimism about achieving the ELV Directive target. No detail was requested in the structured survey about how the target would be achieved. This was discussed during the in-depth telephone and face-to face interviews and the issues and options are discussed in greater detail later in this report.

3.7.2 Investment plans

ATFs were asked about their future plans for investing in additional processing equipment. Figure 28, shows the responses.

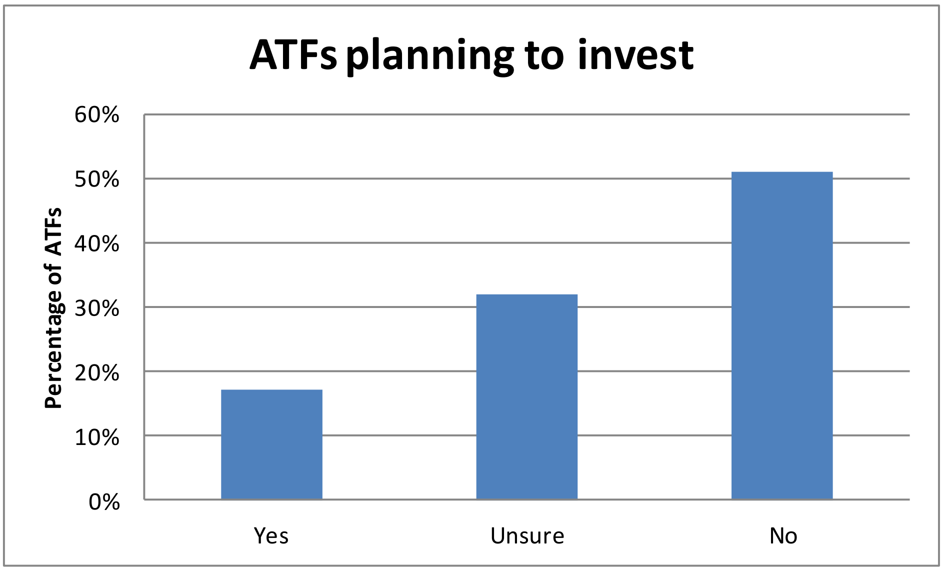

Figure 28 - ATFs planning to purchase additional ELV processing equipment

A total of 12 (17%) of the ATFs interviewed do have plans to purchase additional processing equipment, with a further 23 (32%) unsure. The remaining 23 (51%) said they had no plans to invest.

Of those not planning to invest the following reasons were given:

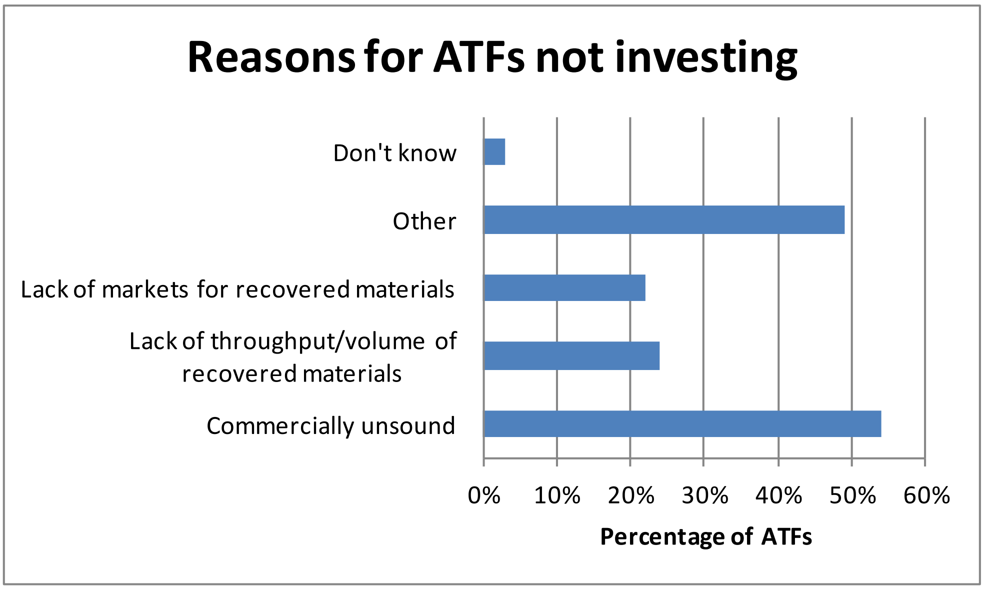

Figure 29 - Reasons for ATFs not investing in additional ELV processing equipment

Note that the percentages add up to more than 100 as respondents could select more than one reason. Clearly, these reasons can be interrelated. For example, a lack of throughput means there is insufficient material to interest buyers and, therefore, investment is commercially unsound. Other reasons given include not investing as lack of demand, operators leaving the sector through retirement and illegal operators.

The reasons given for planning to invest also included increasing the value from recycling and achieving regulatory compliance.

Figure 30, below, shows the types of equipment under consideration for future investment:

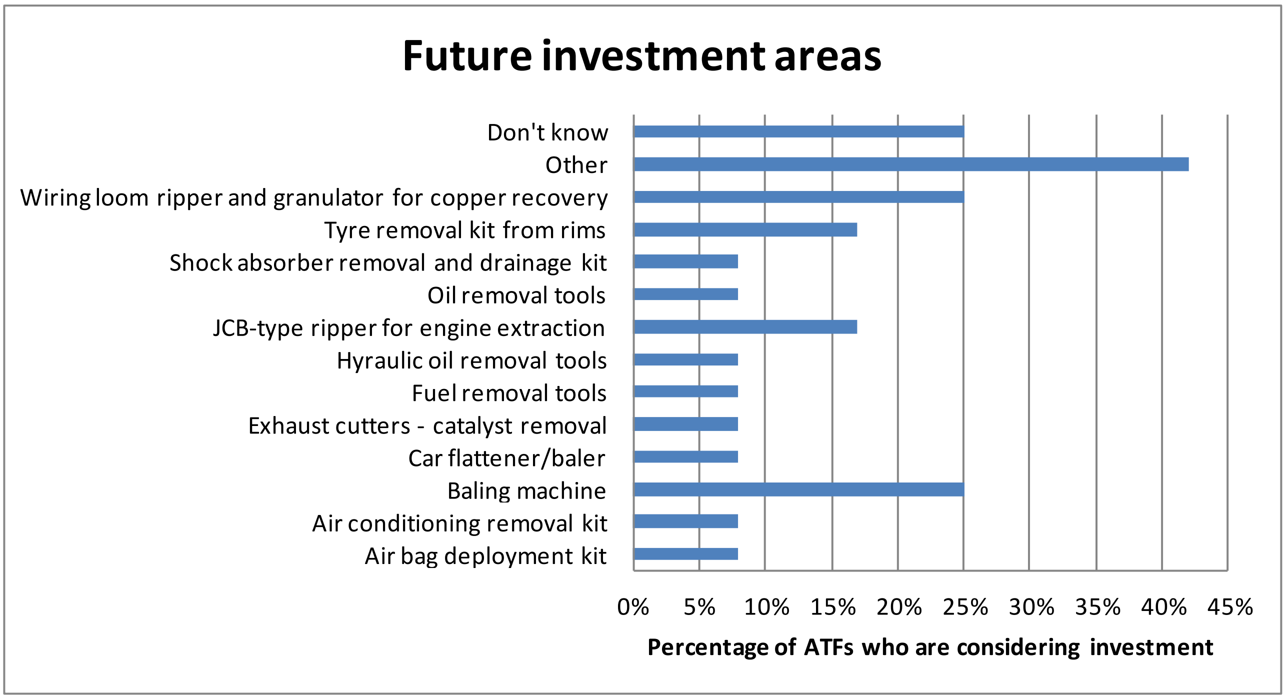

Figure 30 - Types of processing equipment under consideration for future investment (12 responses)

Of those answering „other' the responses included:

- Decontamination unit
- Petrol/water separator
- Loader for stacking cars
- Fork-lift Truck
- Pre-shredder

It is interesting to note that there is a low proportion of ATFs considering investing in air conditioning removal kit even though the earlier figure 19 suggests that few ATFs currently have such equipment available. Given that the removal of air conditioning gases is a mandatory legislative requirement this suggests that some ATFs are not complying fully with regulations.

3.8 Issues with ELV regulations

Respondents were asked if there were any issues with current ELV regulations which, if addressed, could increase commercial opportunities for their companies. Figure 31, below, summarises the responses.

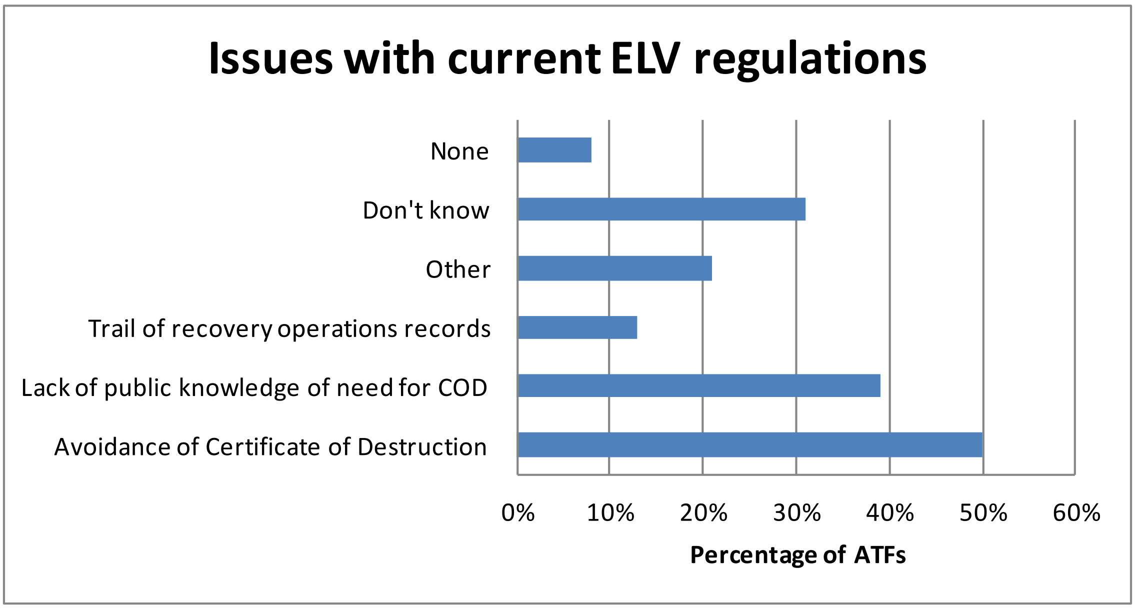

Figure 31 - Issues with current ELV regulations that impact on commercial opportunities (72 responses)

The above figure clearly demonstrates that the COD system is a key issue for ATFs.

Of those who responded „other', the majority made comments about the presence of unauthorised operators damaging their business.

3.9 Shredder operations

Four of the larger shredder operators in Scotland have been interviewed (either face-to-face or via telephone) to ensure the information was as accurate as can be expected in an industry where inputs are variable dependent on economic activity.

A summary of the ELV inputs and outputs was provided in figure 25. Starting with a shredder input of 97,700 tonnes from ELV sources, the operators already separate for recycling 77,350 tonnes (79%), leaving a landfill residue of 20,350 tonnes (21%). Note this only refers to shredder residue from ELVs (total shredder residue from all input sources is estimated to be in the region of 60,000 tonnes p.a.).

All four would like to see a Scottish solution to the problem of having to source an alternative to landfill for non-recoverable material. While there seems to be an emerging market of companies based in England offering the ability to treat shredder residue to the point of contributing to the 95% target, this is likely to be at a cost of around £70/tonne. The additional transport cost means that this option is currently unattractive, compared to landfill. That will change once the landfill tax escalator impacts further.

Feedback from the four shredder operators interviewed indicates:-

- One is pessimistic about being able to reach the 95% level unless energy production is utilised
- Two think it can just about be done by additional investment in sorting plant, with subsequent energy recovery
- Another thinks as the two above, but with a greater focus on material use, which the others may see as landfill residue (e.g. fines and glass)

A common theme is energy production from the residue, and possibly other materials such as tyres, which have uncertain markets. The high calorific value of ASR (mainly due to plastic content) could be an issue with its use in energy production, which may require blending with other materials with a lower calorific value - *"The large PVC content (that can be up to 20%-wt in some ASRs) will put restrictions on thermal processing of ASR for reasons of equipment corrosion risks. Problematic compounds in ASR that often leads to its classification as hazardous waste are PCBs........a third problematic ASR fraction are trace elements and heavy metals*"[40].

Forthcoming transposition of the Industrial Emissions Directive into UK law, through a revised Integrated Pollution Prevention and Control (IPPC) regime, is likely to have an impact on the treatment of ASR produced by shredders with a capacity exceeding 75 tonnes per day (indirectly, through less resources being available to the shredders to invest in further PST). This applies to new sites operational after January 2013 and will be phased in for existing plants from 07/01/2014. SEPA are working with the industry to produce a Best Available Technology Reference document (BREF) to reflect what can be done on a technical basis to reduce waste. Estimates from industry suggest that implementation costs will be hundreds of thousands of pounds (which may impact on availability of investment capital for PST processes, unless this is covered in the BREF document).

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[40] *Zoras, A. Et al, „Automotive industry challenges in meeting EU 2015 environmental standard", Technology in Society 34(2012) pp. 55-83*

4. Wider review of practices and technologies available

This section includes a wider review of practices and technologies currently use in ELV dismantling, shredding and post shredder treatment. Some of these practices and technologies are currently used in Scotland and others can be found in different geographical areas. Before describing these technologies it is useful to consider one of the fundamental issues in the recycling and recovery from ELV: the optimal balance between dismantling and shredding (and the use of Post Shredder Technology (PST)). Practices and technologies used for dismantling, mechanical shredding and PST treatment of ASR are then discussed. Finally, a summary of technologies used in the recovery of rare earth and valuable metals is provided.

4.1 Optimum balance between dismantling and investment in PST

Manual dismantling of parts and materials from ELVs can achieve a certain level of recycling and recovery but feedback, from many in the industry, suggests that achieving the 95% target by 2015 will only be economically possible through investment in PST treatment of ASR. This extract from a relevant study[41] illustrates this view:

"Pro-active European investment would suggest that post-fragmentation material recovery is the preferred option for achievement of the higher recycling and recovery levels...... It is widely perceived within the vehicle recovery sector that the economics of manual material removal is not viable based on UK labour wage rates."

The study found that if ELV operators were to meet the 2015 recycling target by increased manual dismantling alone (i.e. assuming no improvements in post shredder technology – from the time of this 2006 study) then this would be done mainly by the removal of plastic and rubber components totalling 5%+ of the ELV weight. The study found that this would cost the ATF 12 Euro per ELV (taking into account the price received for the recovered material less labour and transport costs). Considering dismantling of only those components where it was economically feasible to remove, this would result in 0.75% of the ELV weight being extracted, with the target components being large, heavy sub-components (such as bumpers and internal trim). Obviously this is sensitive to labour costs and the market price for recovered material.

This research is supported by other evidence on the manual removal of plastic parts from ELV. It suggested that the first 70kg *"can be removed relatively cost-effectively.....with a steep increase in costs for removal of larger quantities of smaller parts".*

[41] Coates, G. et al, „Assessing the economics of pre-fragmentation material recovery within the UK', Resources, Conservation and Recycling 52(2007) 286-302

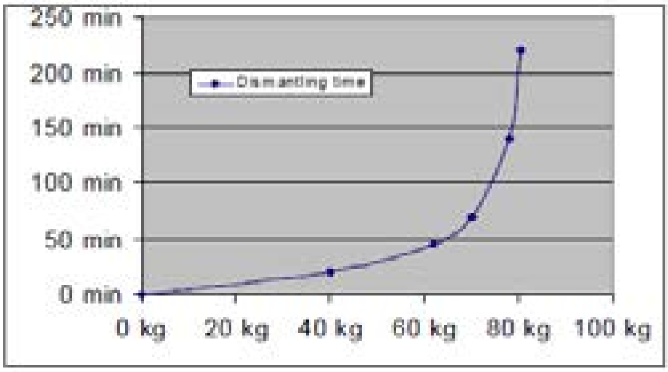

Figure 32 - Dismantling time for a car (total plastics 160kg)[42]

The availability, however, of advanced mechanical separation may offer a more cost effective recycling option and lead to plastic being left on (even though a higher quality material could be obtained with manual dismantling): *"It is extremely unlikely, where advanced separation was used to obtain a mix of sorted plastic for recycling, that more expensive dismantling of plastic parts would take place"[43].*

Industry feedback, obtained during this project, suggests that manual dismantling of plastic parts is a very limited practice in the UK. Aside from the economics of labour rates versus time taken to remove the part, there are also potential issues with metal inserts (used as fastenings in bumpers) causing an issue with plastic recycling operations.

At levels of income varying between £125 and £175 for baled or crushed ELVs, as input material to a shredding operator, the value of material extracted (prior to selling to a shredder operator) has to exceed these amounts by a considerable margin to repay the labour cost of manual removal. It is only when items of high intrinsic value (or particularly sought after spare parts) are involved is the shift from shredding likely to be economical.

4.2 Current recycling and recovery equipment and practices

This section describes the recycling and recovery equipment and practices currently used by ELV dismantlers and shredders in Scotland.

4.2.1 Depollution and dismantling

As detailed in section 3.2.5, there are minimum mandatory depollution processes which must be carried out by ATFs to comply with legislation. Some of the key equipment used in the depollution process is described below.

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[42] Commission staff working document accompanying the report on the targets contained in article 7(2)(b) of directive 2000/53/EC on ELV – impact assessment SEC(2007)14, p.54

[43] Commission staff working document accompanying the report on the targets contained in article 7(2)(b) of directive 2000/53/EC on ELV – impact assessment SEC(2007)14, p.52

Equipment used in the depollution process

There are many pieces of equipment available to aid the depollution process and all of these items are commonly used across Europe and the world. They include:

- Equipment which safely drills fuel tanks and hydraulically removes fuel;
- Drainage/collection equipment for oils, hydraulic fluids etc.; and to remove oil from shock absorbers;
- Tools to remove the catalytic converter;
- Equipment for removal and safe storage of air conditioning gases;
- Equipment for airbag detonation and;
- Equipment for removal of seat tensioners

Other Equipment Used by some Operators

Whilst most ATF's should have equipment for the depollution process, some operators have additional equipment; with the use of such extra equipment usually driven by the volumes handled. Examples include:

- Car Flattener
    - Used to decrease volume when the hulk is transferred to the shredder operator. This helps lower the transport costs per tonne
- Baling Machine
    - Used for the above reasons and additionally enables a volume to be transported longer distances (i.e. 20 bales on flatbed lorry). This provides ATFs the chance to sell to a wider selection of shredders to help achieve a higher price, although processing them tends to be more energy intensive than with flattened ELVs. Only viable if there is sufficiently high throughput of ELVs
- JCB Grab/Engine Ripper
    - Some operators remove the engine for recycling. This is carried out as the value of the engine scrap metal is higher than the hulk light iron price. Engines are sold in bulk to specialist operators. As with baling machines, this is only viable if volumes of ELVs are sufficiently high.
- Wiring/Engine Ripper
    - This equipment is new to the UK and is an American machine, marketed by a Scottish company. It enables operators to use a set of mechanical jaws to rip out small targeted parts whilst also being able to handle the full ELV.

Again, the equipment is only viable if volumes of ELVs are sufficiently high. A cost analysis of this system was recently reported[44]:

"The whole idea of the [equipment] *is to be able to separate the bulk (not every last little bit) of the high value metal quickly and efficiently from the elv. The data shows that the trained operator handles between 50 and 55 cars per day. This is down slightly from the 60 elv‟s per day claim in the original article, but then, this is what has happened over an extended period so we can assume that it is the realistic figure in an ongoing work environment.*

From a starting point, let‟s take the total tonnage baled over the period which is 2367.83 tonnes. If this was baled as previously, all would have been sent to the shredder and the return would have been £414,063. That‟s baled, complete with engines, gearboxes etc. This figure is our default figure. What [the operator] *would have achieved without any extra effort.*

Using the [equipment], [the operator] *separated the following quantities of materials into the following streams:*

- *Bales - 1993.28 tonnes = £348,171*
- *Steel (engines) - 183.94 tonnes = £53,061*
- *Aluminium Alloys (engines, gearboxes, ABS units) - 151.36 tonnes = £60,534*
- *Aluminium Alloys (heater matrixes, air con radiators and pipes) - 6.62 tonnes = £4,965*
- *Mixed Copper alloys (matrixes) - 0.9637 tonnes = £1,392*
- *Copper (matrixes) - 0.5599 = £1,512 tonnes*
- *Copper (wire) - 19.92 tonnes = £35,856*
- *Copper (brake pipes) - 0.1102 = £440*
- *Starters & alternators - 11.58 tonnes = £10,422 - removed manually after engines/gearboxes have been removed*

The above tonnages and values are the actual figures that [the operator] *achieved from the 2,482 ELVs processed and as such gives a reasonably accurate analysis and breakdown. Other factors that must be considered are that 436 of the vehicles had no engine, 424 had no gearbox and 90 had no wiring loom. When you add all these figures up, you get a difference in return of £124,318. The labour costs have been quantified at £11,590 and fuel used during the trial was £2,237. So, apart from the cost of the machine and maintenance costs (which should be included), there isn‟t much missing. When the fuel and labour are included you end up with an increase in return of £110,491 which*

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44 http://www.atfprofessional.co.uk/1204overton.aspx

represents a gain of just under 25%. Or to put it another way, that's an increased return per vehicle of £44.51".

Alongside the above equipment, some operators are purchasing machinery to granulate the copper wiring looms and selling the resulting copper for recycling (current value £4,000 per tonne as opposed to £1,500 per tonne for un-stripped cable). It should be noted, however, that the stripped cable weighs around 35% of the un-stripped cable. If this practice becomes widespread it is likely that shredder operators would reduce the price paid for scrap hulks without engine and wiring looms as they previously gained the financial benefit from recycling these materials.

4.2.2 Mechanical Shredding

At the four shredding plants in Scotland which were interviewed, a typical approach used to deal with „raw' input materials is illustrated below. This is the stage beyond depollution where items such as batteries and catalytic convertors have been removed manually:

- Incoming materials, whether baled, flattened or non-flattened (but depolluted) ELVs, or other light mixed scrap are stockpiled for processing through a hammer mill process
- The nature of inputs means that the operators tend to see the input as a metal resource rather than simply ELVs for processing (it is, therefore, mixed with other input materials in a continuous process)
- Having gone through the hammer mill process the „balled' metal (see image overleaf) and other material can be further treated by magnetic and eddy current separation to realise further value by segregation of metals

Processed light scrap (output from the hammer mill)

- After the magnetic and eddy current separation there is a degree of manual sorting, with a focus on high value items of non-ferrous metal such as remains of wiring looms (insofar as ATFs or initial scrap merchants have not already removed them)
- The mix of material goes through further shredding to take the „balled' material to smaller size, allowing smaller size fractions of ferrous and non-ferrous metals to be identified, segregated and made ready for onward sale to processors/refiners

The remaining material is classed as automotive shredder residue (ASR), which consists of „fines' and a „light fraction' as shown in the images overleaf.

Fines **Light fraction**

There is evidence of at least one shredder conducting pilots to hand sort non-metallic materials from the light fraction, for example, plastics and rubber, as shown in the images below.

Plastics sorted from light fraction **Rubber sorted from light fraction**

These pilots demonstrated that the value generated from the separated materials (less the labour cost of sorting) was not sufficient to make the process economic, relative to disposal via landfill. Indeed, the shredder found very limited or no markets for the sorted plastics and rubber.

4.2.3 Post Shredder Treatment (PST) of ASR

In Scotland there is ongoing work being carried out by shredders on the material processing capabilities of their plants. These additional processes are mainly more refined mechanical separation, including optical sorting. Some of these may mirror practices identified in figure 33, below[45], which shows examples of technologies used across Europe. Technologies that are beginning to be used in Scotland include:

- Micro shredding/granulation
- Optical sorting
- Flotation and sinking tanks
- Further eddy current and magnetic separation

Use of these technologies can establish resource streams of ferrous metals, stainless steel and mixed non-ferrous metals, which are of higher value than simply leaving the larger sized „balled' metal fraction intact. Beyond this metallic sorting, other technologies and processes are being investigated to deal with the fines, plastics, rubber, foams and wood, which are the main components of the residue.

It would appear that the shredder operators in Scotland are looking at elements of these waste streams and evaluating options to deal with them (for example, the pilot trial to hand sort plastics and rubber from the light fraction). This is, however, on more of a „piece-meal' basis than what might happen at a purpose–built PST plant (such as those currently operating and being developed in England and overseas that are achieving, or getting close to, the 95% recovery level).

Shredders in Scotland highlighted approaches received from waste management companies with a view to using the ASR as a feedstock for Refuse Derived Fuel (RDF) or Solid Recovered Fuel (SRF). The UK Government position on the use of thermal treatment for ASR is that this can be counted as recovery subject to minimum thermal efficiencies being achieved[46].

Whether there is a case for moving beyond current investment in Scotland to a purpose-built PST plant will be further explored in section eight of this report.

A number of PST technologies have been identified and these are summarised in figure 33.

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[45] *Taken from Zoras, A. Et al, „Automotive industry challenges in meeting EU 2015 environmental standard", Technology in Society 34(2012) pp. 55-83*

[46] http://www.mrw.co.uk/news/bmra-welcomes-elv-energy-recovery-decision/8638206.article

Name of technology/developer	Type of technology	Level of technology development	Approximate outputs from process	Overall rate of RRR %	Recycling rate RR %
VW – Sicon	Mechanical separation	1 trial plant 8000 t plus 2 under contruction. Plans for a 100,000	Shredder granules 36%, shredder fibres 31%, metals 8%, wastes 26%	74	74
Galloo	Mechanical separation	Operating plants	Recycled plastics 9%, metals 30%, refuse derived fuel 13%, wastes 48%	52	39
Suit	Mechanical separation	Operating plants in Japan	Organic plastic 50%, mineral 20%, metals 10%, water 20%	100	80
R-Plus	Mechanical separation	Operating plants	Organic fraction 60%, metals 5%, minerals 35%	100	100
Citron	Thermal treatment - ox reducer	1 trial plant (130,000 t, 12,000 ASR).	Curent – Ca Fe concentrate 45%, Zn concentrate 4.3%, Hg 0.7%, wastes 50%	50	50
		Plans for a 500,000 t (120,000 ASR) plant	Plan Ca Fe concentrate 45%, Zn concentrate 4.3%, Hg 0.7%, recovery 50%	100	50
TwinRec	Thermal treatment - gasifier	Operating plants in Japan	Metals 8%, glass granulate 25%, recovery 52%, wastes up to 15%	85	33
SVZ Schwarze pumpe	Thermal treatment - gasifier	Industrial trial plant	Synthetic gas 75%, metals 8%, wastes 17%	87	8
Reshment	Mechanical separation thermal treatment	No pilot or trial plants	Not available	Not available	Not available

Figure 33 - Overview of Post Shredder Technologies[47]

Figure 33 provides an overview of the main existing post shredder technologies and developers from around the world.

An example of an organisation currently operating mechanical separation plants is Galloo Plastics, a sister company of Belgium based Galloo Group. The Galloo Group operates ELV shredding plants and other recycling facilities in Belgium, the Netherlands and France. Their plastic recycling process involves[48]:

- Grinding ASR to a 25mm size
- Wet density separation (provided by US company Engineering and Separation Technology LLC)
- Size classification
- Air classification
- Eddy current separation (to remove remaining metals)

[47] *Zoras, A. Et al, „Automotive industry challenges in meeting EU 2015 environmental standard", Technology in Society 34 (2012) pp. 55-83*

[48] „Breakthrough Moment', Recycling Today Global, pp. 30-32, May 2012

Galloo Plastics claims it is set to produce 25,000 tonnes of granulate per year (from end of life consumer electronics and ELV). It exports 40% of this material from its French plant, mainly to Europe (including for use in vehicle production) but also to Brazil and Mexico.

Figure 34, below, provides a summary of the processes used in various PST operations.

	Argonne	Galloo	MBA-polymers	Salyp process	Stena	R-plus (WESA-SLF)	VW-Sicon
Separation techniques							
Air classification	X	X	X	X	X	X	X
Magnetic separation	X	X	X	X	X	X	X
Eddy current separation	X	X	X	X	X		X
Screening		X		X	X	X	X
Trommel separation	X	X		X	X		
Optical sorting				X			X
Manual sorting					X		
Drying						X	
Float/sink separation		X		X	X		X
Froth flotation	X						
Thermo-mechanical sorting				X			
Wet grinding			X				
Hydrocyclone			X				
Static, hydrodynamic separation tanks		X					
Heavy media separation					X		
Status of development	Operating plants	Operating plants	Operating plants	Operating plants	Operating plants	Operating plants	1 trial plant + 2 under construction
Overall recovery rate	90% of polymers > 6 mm 90% of metals > 6mm	90%	Not given	86%	80%	92%	95%

Figure 34 - Overview of processes used in post shredder technologies[49]

The new ASR facility, being developed in the Netherlands (with investment provided via their ELV funded system), uses VW-Sicon technology and plastics are sent for onward processing at Galloo.

In addition to the PST technologies summarised above, the following systems are also of interest[50]:

Agilyx

Agilyx (www.agilyx.com) are based in Oregon in the US. The company claims to have a patented technology to convert plastic waste into a synthetic crude oil. The plant is said to be capable of processing ten tonnes of plastic per day (to produce 2,400 gallons of oil). Capacity can be increased by adding to the modularised system.

Vadxx

Vadxx (www.vadxx.com) claims to have developed a technology that can convert ASR into a synthetic crude oil, a natural gas and a carbon char product. The company further

49 Vermeulen, I. et al, „Automotive shredder residue (ASR): Reviewing its production from end-of-life vehicles (ELVs) and its recycling, energy or chemical valorisation', Journal of Hazardous Materials 190 (2011) p. 16

50 „Breakthrough Moment', Recycling Today Global, pp. 30-32, May 2012

claims that the system can breakeven at crude oil prices of between $35 and $40 per barrel (less than half the current oil price at the time of writing).

Chinook Sciences

Chinook Sciences (www.chinooksciences.com) is a US based company that claims to have a patented gasification technology that can process ASR. Chinook has an office in Nottingham due to „considerable interest' from the UK market and provides technology to one of the large shredders in the UK.

The PST plant modelled as part of this project (and described in section eight) is based on feedback from two operational PST plants. In both cases the minimum commercially viable throughput of shredder residue is 100,000 tonnes per annum and the investment cost was between £20 million and £25 million. A third plant was identified, via secondary information sources, with a stated commercially viable capacity of 60,000 tonnes. Despite attempts to make contact with the operator of this plant we were unable to obtain more detailed feedback in the time available.

4.2.4 Recycling and recovery technologies to extract valuable metals and rare earth elements

High value metals

The recovery of high value metals is a well established part of the ELV sector, as described in section 6.3. The technologies used to extract high value metals are either pyrometallurgical (e.g. smelting and refining) or hydrometallurgical (e.g. using chemicals to separate and extract metal types). The facilities that carry out this high value metal extraction are characterised by large physical footprints and high capital investment costs. There are, therefore, relatively few facilities in Europe, with only one being identified in the UK (that extracts platinum group metals from catalytic convertors).

Rare earth elements

„The recycling of rare earth elements from electronic devices, for example, is currently challenging from a technological but also from an economic point of view.....this situation calls for targeted innovation and research efforts, breakthrough technologies and multidisciplinary approaches to bridge gaps in our knowledge'[51].

One of the main issues in extracting rare earth elements is that they are present in small amounts in parts and components and this concentration is diluted even further when faced with a volume of shredder residue. The level of input material required to obtain commercially viable levels of rare earth element recycling is significant, with one Japanese

[51] „Making raw materials available for Europe's future wellbeing – proposal for a European innovation partnership on raw material', European Commission communication – COM(2012) 82 final, 2012, p.3

company seeking to commercially process 100 magnets per hour in its new plant (see over page for more detail).

Rare earth elements are present in a number of parts and components. A recent study, conducted jointly by Ford and Massachusetts Institute of Technology identified the 12 parts and components containing rare earth elements and their respective rare earth element content[52]. Figure 35, below, summarises this data.

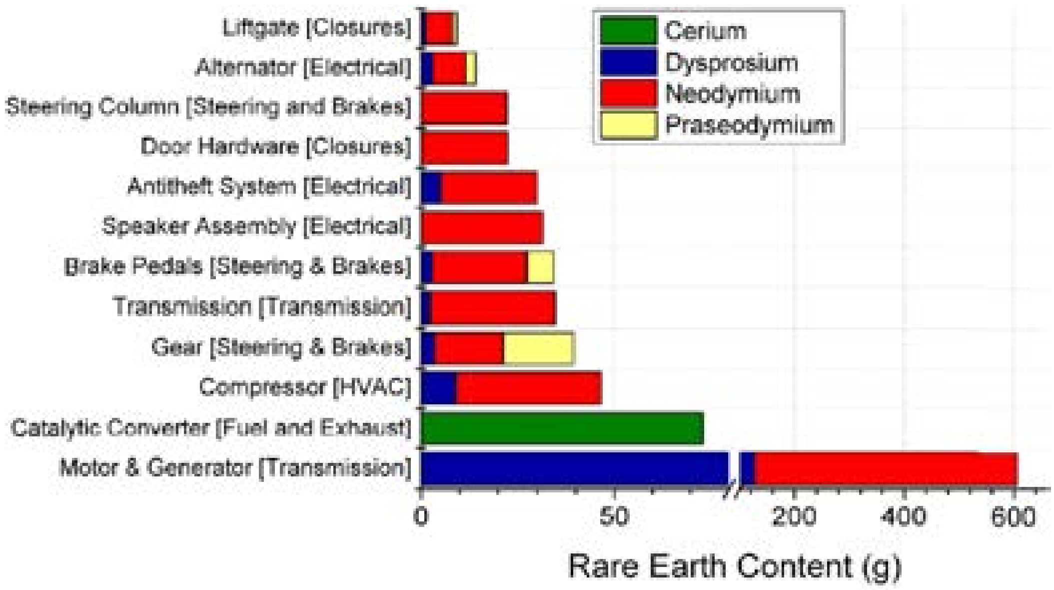

Figure 35 - Top 12 vehicle parts containing rare earths and their rare earth content

The study estimated that there was 0.44kg of rare earth elements in a „typical mid range US sedan' and that 80% of this was contained within magnets. For a full hybrid vehicle with a lithium ion battery, the estimated weight of rare earth metal content rose to 1.05kg per vehicle (obviously the additional amount of rare earth elements being contained in the battery). A full hybrid with a nickel metal hydride battery was estimated to have a rare earth element content of 4.5kg per vehicle (again with the additional amount of rare earth elements being contained in the battery).

A search of technologies capable of extracting rare earth elements has identified a number of pre commercial developments in Japan, where the government has set aside some $1.2bn for research into rare-earth recycling, as well as opening new supply routes and stockpiling rare earth elements. The government is also drafting legislation to promote the

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[52] Alonso, E., Wallington, T., Sherman, A., Everson, M. et al., "An Assessment of the Rare Earth Element Content of Conventional and Electric Vehicles," *SAE Int. J. Mater. Manf.* 5(2):2012, doi:10.4271/2012-01-1061.

re-use of rare earth elements from used products[53]. Kosaka Smelting and Refining (a subsidiary of Dowa Holdings) is attempting to recover rare earth elements, such as neodymium, using a smelting a refining process[54]. Hitachi is working on a dry extraction process to recover neodymium and dysprosium from rare earth magnets. This facility is expected to be fully operational in 2013, automatically processing 100 magnets per hour compared to ten magnets per hour using a manual process. The company is targeting a 10% recycling rate for rare earth elements by 2013[55]. Toyota is working jointly on the issue with Panasonic to recycle lanthanum and neodymium from hybrid vehicle batteries (this also involves joint working with SNAM in France). Honda is working jointly with Japan Metals & Chemicals to establish a large scale facility to recapture rare earth elements from Honda parts (with claims that up to 80% of rare earth elements can be recovered from nickel metal hydride batteries)[56].

Umicore, a major Belgium based metal refiner, has also developed a process for recycling rare earth elements from nickel metal hydride rechargeable batteries[57].

A German led partnership project (MORE – MOtor REcycling) has been funded by the German Federal Research Ministry. The project is led by Siemens and also involves Daimler, Umicore and several universities and research institutions. The objective is to investigate different approaches to the recycling of electric motors from vehicles, such as: the dismantling of the magnets; the repair, refurbishment and reuse of the electric motor or its components; and the recycling of magnetic materials and rare earth recovery from pre-sorted and shredded material[58].

GreenRock Rare Earth Recovery Corporation, in the US, plans to establish four rare earth recovery facilities processing 277,000 tonnes of consumer electronics, magnets, phosphors and industrial batteries per annum[59].

In Norway, the state research organisation has funded a project to develop techniques for extracting rare earth elements from permanent magnets. The project is investigating the potential of technology transfer from the aluminium smelting industry[60].

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[53] „Rare earth metals in short supply?', article in Engineering and Technology magazine, 23rd April 2012
[54] „Japan Recycles Minerals from Used Electronics', article in the New York Times, 10th October 2010
[55] „Hitachi technology to recycle rare-earth magnets', article in Recycling International website, 2012
[56] „Honda announces large rare earth recycling effort', article in Ceramic Technology Today, 23rd April 2012
[57] „Rare earth metals in short supply?', article in Engineering and Technology magazine, 23rd April 2012
[58] „Research into rare earths from electric motors', article in Recycling International, Jan/Feb 2012, p.8
[59] „Rare Earth Element Recycling Joint Venture Launched', article in Waste Management World, 18th February 2011
[60] „Engineers seek to extract rare earth metals from scrap', article in The Engineer website, 19th September 2012

5. ELV sector development in other countries

A number of different systems operate in other countries to deal with ELVs and there are examples of different practices being employed. This section provides an overview of systems and practices operating in a number of European countries. It also summarises the approach to ELV treatment taken in Japan.

A number of sources have been used to identify the situation in different countries. These include personal correspondence with individuals involved in ELV treatment in different countries[61], a published report prepared for the European Parliament and various papers and articles[62,63&64].

5.1 Overview of the requirements of the ELV Directive

The ELV Directive[65] provides for a number of conditions that national systems and practices should adhere to. Some key aspects are listed below to help set a context for the differences that are apparent at national level.

„A certificate of destruction, to be used as a condition for the destruction of end-of like vehicles should be introduced....This certificate shall be issued to the holder and/or owner when the end-of-life vehicle is transferred to a treatment facility".

Vehicle registration systems can operate differently in different countries. For example, in Austria a vehicle is deregistered when the ownership changes, which is not the case in the UK.

A recent report[66] highlights that *„there is indication given that the existence of the registration document notification route has reduced the significance of the COD in the UK"* – referring to the fact that the last owner of a vehicle can complete the DVLA form V5C, confirming they have transferred the vehicle to a dismantler, and the DVLA confirms they are no longer responsible for the vehicle without any apparent systematic check being

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[61] Feedback was received from members of the European Group of Automotive Recycling Associations about the situation in Ireland, Switzerland, Poland, Netherlands, Denmark and Sweden

[62] Togawa K., „Japan's Automotive Recycling System: Evaluation Three Years after Implementation', in Promoting 3Rs In Developing Countries. Lessons from Japanese Experiences, Edited by M. Kojima, IDE Spot Survey 30, Institute of Developing Economies, IDE-JETRO, pp. 107-124, 2008

[63] Kitagawa K., „Automotive Recycling in Europe, Japan & North America', Presentation by the JICA Expert Team for ELV Management Plan in Mexico, Japan Productivity Centre

[64] Willis K.P., Osada S. & Willerton K., „Plasma gasification: Lessons learned at EcoValley WTE Facility' [Japan], Proceedings on the 18th Annual North American Waste to Energy Conference, May 2010

[65] Directive 2000/53/EC of The European Parliament and of The Council of 18 September 2000 on end-of-life vehicles, Official Journal of the European Commission, L269/34, 21.10.2000

[66] „End of Life Vehicles: Legal aspects, national practices and recommendations for successful approach'. DG for Internal Policies for the European Parliament, IP/A/ENVI/ST/2010-07, October 2010

made that a COD has been issued. The deregistration systems in some other countries have linked the production of a COD to a financial reward to the last owner of the vehicle which means there is an economic incentive to ensure the COD is obtained.

„Member States shall take the necessary measures to ensure that the delivery of the vehicle to an authorised treatment facility.....occurs without any cost for the last holder and/or owner as a result of the vehicle having no or a negative value".

In the UK, since the Directive was transposed, the market value of ELVs has typically been positive; therefore, a cost is not usually passed onto the producer.

5.2 Systems used in different European countries

There are two basic types of system employed within Europe as a result of individual countries transposition of the ELV Directive into national legislation. The first type is a funded system where monies are made available to incentivise behaviour of actors in the ELV system (e.g. encouraging last owners to take the ELV to a registered treatment facility, paying dismantlers to remove specified parts of the vehicle). The second type of system is an unfunded system (e.g. the UK, Sweden, Ireland, etc.) where the treatment of ELVs is purely market driven.

A selection of funded ELV systems are described below.

Netherlands

In the Netherlands, there is a funded system managed by a dedicated company, ARN. The first owner of the vehicle pays an additional fee via the importer (currently 45 Euros (£36)), which goes to ARN. This money is distributed to the ATFs that contract with ARN based on the amount of material dismantled (including plastic bumpers and dashboards for example). If all specified materials are dismantled the ATF can earn up to 60 Euros (£48) per vehicle from ARN. Note that the fee is regarded as necessary to subsidise the plastic removal in a situation that would otherwise be uneconomic. Obviously, not all ATFs dismantle to this level as ARN cover costs by the initial 45 Euro (£36) per vehicle fee.

Previous fund surpluses have been invested by ARN in developing an ASR processing plant. No direct Government funding was provided to develop the plant but the Government do provide some financial support with ongoing research and development costs. Once this is fully operational, ARN intend to change their policy regarding plastic bumpers and dashboards as it will be more economically efficient to recover the plastic from the ASR than to pay dismantlers to manually remove them.

In the Netherlands, the COD is the same certificate last owners receive in any case to relieve them of their legal obligations. Without this certificate the owner is still liable for tax, MOT and insurance connected to the vehicle and there is, therefore, a significant driver for the last owner to obtain this certificate (if there is effective enforcement of this break in liability).

Denmark

In Denmark there is a funded system with vehicle owners contributing via annual payments of insurance cover. The last owner is rewarded from the fund when the ELV is delivered into the legal ATF network and paperwork completed. The current payment is DKK 1750 (£188).

The levy paid on the purchase of a new vehicle is placed in a fund which allows the last owner who hands in the vehicle at the end of life to be rewarded for bringing the ELV into the legal regulated ATF system. Monies will only be paid out once the certificate of destruction has been issued.

Norway

In Norway, a scrap deposit/premium system has been introduced with the objective of ensuring that ELV's are only treated at a licensed facility. Unlike in the Netherlands, the fee is not paid to the ATF but the deposit is 100% returned to the last owner (providing them with an incentive to return to a licensed ATF). The initial deposit of NOK 1300 (£140) is paid, by the first owner, to the Norwegian Custom Authorities that operates the web based COD system. The dismantler registers the details about the ELV and the person who delivers the car, and the person to receive the deposit return (these can be two different people). The Norwegian Customs Authorities then approves this and issues a COD to the ELV owner, the dismantler and holds an electronic copy for itself. The dismantler must keep the COD for ten years. The return of the deposit is then made direct to the last owner within 1 to 3 weeks.

Poland

In Poland, there is a fee on the purchase of a new vehicle of PLN 500 (£97), which is paid to The National Foundation for Environmental Activity. ATFs can, each year, submit data returns to this organisation and receive PLN 500 (£97) per 1000kg of ELV treated to the correct standards. There is a limit on the amount each ATF can claim of 200,000 Euro (£160,546) in a 3 year period.

5.3 Practices employed in different European countries

Annex 1 of the ELV Directive states a number of minimum technical requirements for the treatment of ELVs in order to promote recycling:

- *„Removal of catalysts*
- *Removal of metal components containing copper, aluminium and magnesium if these metals are not segregated in the shredding process*

- *Removal of tyres and large plastic components (bumpers, dashboard, fluid containers, etc), if these materials are not segregated in the shredding process in such a way that they can be effectively recycled as materials*
- *Removal of glass"*

This section of the ELV Directive was transposed to Scottish regulations[67] as:

„Any treatment operations are carried out in such a way as to allow the removal and subsequent recycling of:

- *The catalyst or catalysts*
- *All metal components containing copper, aluminium or magnesium (including during shredding)*
- *Tyres (including during shredding)*
- *All large plastic components (including during shredding)*
- *Glass"*

Currently, in Scotland, no significant removal or subsequent recycling of plastic or glass at the dismantler stage, or from post shredder ASR, was identified through industry interviews (other than where the materials were contained in parts and components removed for reuse at the dismantling stage). Separate feedback from one other stakeholder suggested that glass was removed during the processing of ASR in some shredders in Scotland but this was not confirmed during interviews with four of the largest shredders.

In the rest of Europe there are different practices that result in different levels of recycling and recovery being claimed. Different Member States, however, classify the same technical treatment options in different ways. A recent report[68] highlighted the following examples of these different interpretations:

<u>Use of plastic streams obtained by post-shredder treatment in blast furnace</u>

Some Member States account for the total amount of the used quantities for recycling (reducing agent), others account only a proportion of the amount introduced into a blast furnace as recycling whereas the remaining proportion is accounted for as thermal recovery.

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[67] The End-of-Life Vehicles (Storage and Treatment) (Scotland) Regulations 2003 – Guidance on the Keeping and Treatment of Waste Motor Vehicles and Conditions of Site Licences, Scottish Environment and Rural Affairs Department, 2003

[68] „End of Life Vehicles: Legal aspects, national practices and recommendations for successful approach'. DG for Internal Policies for the European Parliament, IP/A/ENVI/ST/2010-07, October 2010

Co-incineration of fibre-rich waste streams obtained by post-shredder treatment with sewage sludge

Member States either account it as thermal recovery or as recycling (substitution of dewatering agents for the sewage sludge before incineration).

Use of tyres or shredder residues for landfill-construction, landfill cover or terrain corrections

This is either classified as recovery or disposal. (Note: in the UK the use of whole or shredded tyres in landfill construction is considered as recovery but shredder residue used for landfill is considered as disposal)

Backfilling[69]

Regarding backfilling there are discrepancies in the definitions of recycling and recovery between the ELV-Directive and the new Waste Framework Directive (2008/98/EC). The new Waste Framework Directive, in addition to recycling and thermal recovery, also defines "recovery" which is neither "recycling" nor "thermal recovery" (e.g. backfilling). The targets of the ELV Directive and Commission Decision 2005/293/EC, however, refer to recycling and thermal recovery only".

The above differences are related to how different countries record what happens to ASR. This is crucial to whether a country is able to achieve the 85% recycling and 95% recovery targets for 2015.

Reviewing how ASR is treated across different Member States shows that PST plants are only present in a minority of countries (e.g. Austria, Germany, Belgium, France, Netherlands and UK). In Austria, the output of its' centralised PST plant includes plastic used in a blast furnace, a fibrous material that is mixed with sewage sludge prior to incineration. The remainder is landfilled.

In Germany, ASR is landfilled, used as backfill, used in the construction of landfill and for energy recovery.

In the Netherlands, the ASR processing plant states it can produce:

- A plastics pre-concentrate consisting of polypropylene, polyethylene, ABS and polystyrene a mixture that will be further processed by Galloo Plastics and returned in a closed loop to automotive applications
- A plastics granulate mainly used as a reducing agent and as a replacement for coal or heavy oil in blast furnaces

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[69] Backfilling refers to a recovery operation where a suitable waste is used for reclamation purposes in evacuated areas or for engineering purposes in landscaping and where the waste is a substitute for non-waste materials. For example, using ASR to fill voids in depleted salt mines.

- A fibre fraction used as a de-watering agent for sewage sludge as a replacement for coal dust
- A sand fraction (fines) mainly used as a road construction material and as a backfilling material for old salt mines
- Metals for recycling
- A remaining fraction comprising dust and sludge that will be destined for incineration with energy recovery

According to Annex 1 of the ELV Directive, large plastic components should be removed at either dismantling or during the shredding stage. Figure 36, below, shows the performance of a sample of Member States (who provided the relevant data to Eurostat in 2008) of the removal, reuse and recycling of plastic at the dismantling stage compared to the estimated average weight of plastic obtained in an ELV of 90kg.

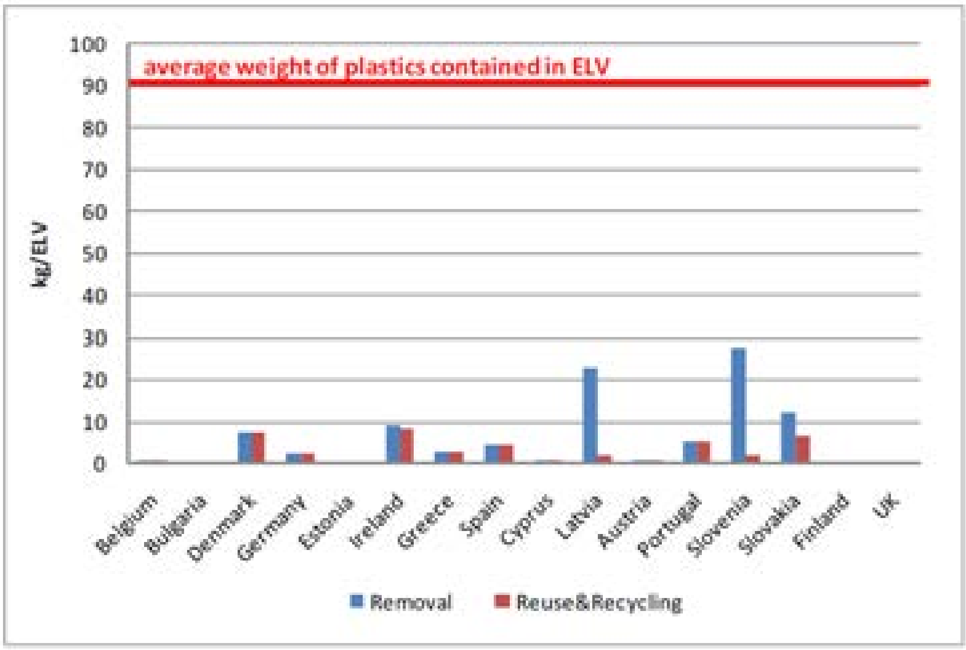

Figure 36 - Large plastic parts derived from dismantling[70]

The above figure shows a relatively low level of removal of plastic at dismantling stage. It is not clear why the removal figures for Latvia and Slovenia should be so far in excess of their reuse and recycling levels.

Although the Netherlands is known to remove bumpers and other large plastic parts (and the ATFs are financially rewarded for doing so), it is assumed that they did not provide

[70] „End of Life Vehicles: Legal aspects, national practices and recommendations for successful approach'. DG for Internal Policies for the European Parliament, IP/A/ENVI/ST/2010-07, October 2010

data to Eurostat for the year concerned. As mentioned previously, it is the intention of ARN in the Netherlands to stop this financial reward after its ASR processing plant is fully operational as it will be more economic to recover the plastic from the ASR.

Annex 1 of the ELV Directive also states that glass should be removed as part of the treatment process. The Directive does explicitly provide for this removal to be carried out as part of the shredding process (unlike for plastic and tyres where no similar explicit statement is made regarding the acceptability (or otherwise) of removal, post shredder). Some countries (such as Austria and Sweden) have a legal obligation to remove at least some of the glass prior to shredding but many do so as part of the shredding process. The latter inevitably results in a „down-cycling' of the material as it is only suitable for aggregate type applications post shredder.

Figure 37, below, shows the performance of a sample of Member States (who provided the relevant data to Eurostat in 2008) of the removal, reuse and recycling of glass at the dismantling stage compared to the estimated average weight of glass obtained in an ELV of 25kg.

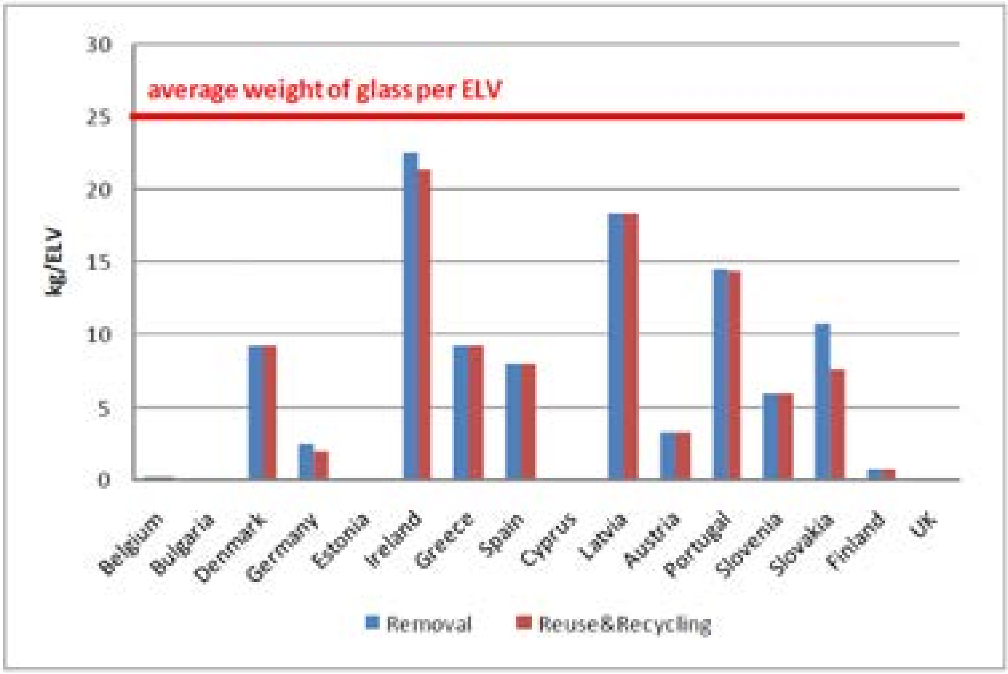

Figure 37 - Glass derived from dismantling[71]

The above figure shows the UK having no significant removal of glass prior to shredding. This is a function of the cost of labour to remove them and the relatively low (if any) value

[71] „End of Life Vehicles: Legal aspects, national practices and recommendations for successful approach'. DG for Internal Policies for the European Parliament, IP/A/ENVI/ST/2010-07, October 2010

that can be achieved from reprocessors in comparison to the value they can achieve through sale of the hulk (complete with glass) to the shredder. It is not clear why there should be such high reported rates in other countries where there is no legal obligation to remove glass prior to shredding and no evidence was identified regarding onward markets.

5.4 Overview of ELV system and practices in Japan

This section provides details of how ELVs are treated in Japan. The key features of Japan's funded ELV recycling system are[72]:

- *„Vehicle manufacturers and importers are responsible for the collection of three specific types of material taken from ELVs: ASR, airbags and fluorocarbon gas contained in air conditioners, which are difficult to handle properly;*
- *A recycling fee must be paid by vehicle users in advance – when they register their cars or when they purchase a new car;*
- *The handling of ELVs is monitored on the Internet in an integrated manner by an electronic information system*
- *The Japan Automobile Recycling Promotion Center, a third party organisation, is assigned to manage collected ELV fees, and to monitor ELV handling information;*
- *Operators must be registered or approved"*

The Japanese ELV system contains provisions for „Whole Vehicle Utilisation'[73]. Under this provision:

- *„Japanese dismantlers have an option to send car wrecks directly to the electric furnaces without shredding processes. This recycling method is called „Whole-Vehicle Utilisation;*
- *This method is also known as ELV recycling without generating ASR because lightweight parts are pressed with treated car wrecks and then they are put together into an electric furnace as supplementary fuel;*
- *In this case dismantlers are required to reduce copper contents into not more than 0.3%. So they have to remove the wire harness from ELVs. Japanese dismantlers remove them by operating heavy machinery"*

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[72] Togawa K., „Japan's Automotive Recycling System: Evaluation Three Years after Implementation', in Promoting 3Rs In Developing Countries. Lessons from Japanese Experiences, Edited by M. Kojima, IDE Spot Survey 30, Institute of Developing Economies, IDE-JETRO, pp. 107-124, 2008

[73] Kitagawa K., „Automotive Recycling in Europe, Japan & North America', Presentation by the JICA Expert Team for ELV Management Plan in Mexico, Japan Productivity Centre

In 2006, the use of the „Whole Vehicle Utilisation route was taken by 10% to 15% of ELVs[74]. This means that ASR is produced from ELVs undergoing the shredding process. There is a current example of ASR processing by plasma gasification in Japan[75]. This plant has capacity for 165 tonnes per day of a 50/50 mix of ASR residue compared to 220 tonnes per day for the MSW only. At 165 tonnes per day this equates to just over 60,000 tonnes capacity.

74 Togawa K., „Japan's Automotive Recycling System: Evaluation Three Years after Implementation', in Promoting 3Rs In Developing Countries. Lessons from Japanese Experiences, Edited by M. Kojima, IDE Spot Survey 30, Institute of Developing Economies, IDE-JETRO, pp. 107-124, 2008

75 Willis K.P., Osada S. & Willerton K., „Plasma gasification: Lessons learned at EcoValley WTE Facility' [Japan], Proceedings on the 18th Annual North American Waste to Energy Conference, May 2010

6. Current markets for ELV parts and materials

This section describes the markets for the various parts, materials and components recovered from ELVs. The section first considers the parts and materials arising from dismantling operations before then discussing markets for materials arising from shredder operations.

6.1 Markets for dismantlers

6.1.1 Spare parts reuse, refurbishment and remanufacturing

The sale of spare parts and components is one of the main ways in which ATF dismantlers generate revenue. Markets for these parts tend to be in the UK (with survey respondents reporting 79.6% of sales of internal mechanical components in Scotland and 20.3% in the rest of the UK) with ATFs either recovering items and holding as stock, or only removing items on demand. A smaller number of ATFs reported removing parts and selling to export markets. Further discussions indicate that more parts and components may end up in export markets than the survey suggests. Some of the sales of internal mechanical components (to Scotland and the rest of the UK) are made to refurbishers/remanufacturers of components (there are at least four engine refurbishers and one transmission remanufacturer based in Scotland) or to core parts suppliers who supply internal mechanical components to refurbishers and remanufacturers based outside of the UK.

With recent advances in information technology there has been a rise in the ability of core parts suppliers to link directly with dismantlers. Some advanced systems on the market enable the dismantler to type a registration number into a system provided online. The dismantler will then be advised which components the core parts supplier will guarantee to purchase and the price they will pay for them. Some systems also have the ability to generate stock control bar codes based on the items the dismantler agrees to sell. These bar codes can then be scanned when the core parts supplier picks up the items.

Some dismantlers have invested in their own IT systems that enable them to sell parts and components via their own websites. Others use third party auction sites to reach consumers with the parts and components they recover from ELVs.

Supplies of reused parts and components direct to vehicle service and repair garages are also part of the market for dismantlers. This is particularly relevant for non-safety critical parts and components, such as body panels, wing mirrors, etc. Where parts are classed as safety critical then the likely route to market is via a refurbisher or remanufacturer. The insurance industry is a driver in the use of reused, refurbished and remanufactured parts (also referred to by the generic term, „green parts') as it offers the opportunity to reduce costs compared to using original equipment from manufacturers or aftermarket parts[76]. There are a number of issues around the use of reused parts, which have been highlighted by different parts of the supply chain. For example, the figure below summaries the key issues and potential resolutions to those issues suggested at a recent meeting of industry stakeholders[77]:

Issue	Resolution
Difficulty locating parts	On-line Single point of contact Adequate stock levels On-line ordering, payment, delivery, tracking
Consistent standards between sources	Quality assurance programme Provide provinance of part supplied
Inaccurate description of parts (actual part or condition)	VRN look-up Part number availability Clear, accurate & consistent description of part condition
Difficulty in returning parts & receiving credits/ refunds Managing expectations	Service Level Agreements Customer services
No discernable structured/consistent parts pricing	Transparent pricing policy e.g. fixed % of retail

Figure 38 - Key issues involved in the supply of reused parts and potential resolutions

The reused parts and components have to compete with both aftermarket and original equipment from vehicle manufacturers. Typically, the advantage of reused parts is that they are lower cost than the two other alternatives. The cost advantage is important but, alone, this will not be sufficient to drive the market for reused parts and components. Service and repair garages demand fast (often same day) delivery of parts and components and expect to have a reasonably comprehensive stock list to choose from. The current suppliers tend to be independent motor factors that hold stock for a large variety of vehicles across a number of brands. Alternatively suppliers can be part of a branded dealer network providing parts and components for only one manufacturer.

Dismantlers can either attempt to service garages directly or via existing motor factors. There has been a recent acquisition of a large motor factor chain by a US based vehicle

[76] Aftermarket parts are new parts but are not produced by the vehicle manufacturers. They tend to be a lower cost option relative to the original equipment supplied by the vehicle manufacturers.
[77] Automotive Recycling UK, MVDA, Issue 115 3rd Quarter 2012, p.15

dismantler group. The view of many in the industry is that the next step for this company will be vertical integration with the purchase of one or more vehicle dismantlers in the UK to secure a supply of used parts and components to distribute through the motor factor group.

There have been a number of trials by groups of dismantlers working with insurance companies and their networks of repair garages. One such trial operated in a „hub and spoke' model of dismantlers. Each dismantler operated as a supplier to the repair garages in their geographical area but was able to source parts and components from other dismantlers in the network. Interestingly, the parts and components supplied in this pilot tended to be items such as glass, bumper mounts, washer bottles, trims and seals (items with high glass, plastic and rubber contents)[78]. Feedback from industry suggests that such pilots are ongoing in Scotland.

There are some specific concerns from vehicle repair and serving garages about the use of reused parts and components related to insurance work (in addition to those listed in figure 38). These relate to the payment model used by the insurance industry to reimburse approved garages for repair work they carry out. Insurers derive costs from a database of information about the average time taken to carry out specified repairs. They tend to cost repairs in multiples of six minute units. Regardless of whether a reused or new part is used the repairer will be paid the same. This means that if there are any defects in a reused body panel (for example) the repairer will not be paid any more money. The end customer will, however, not expect to have any scratches, dents, etc, in their vehicle once it has been repaired. Even in the case where potential corrosion is not visible in a body panel, the repairer is expected to offer a warranty similar to that of a new part. They, in turn, are unlikely to be able to pass this risk back to the dismantler. This issue creates a level of inertia in the development of the market for reused parts and components.

Fleet operators and retail repair and service garages need to have confidence in their supply chains' ability to provide the correct level of quality (both product and service). In 2009, the dismantling industry sought to address this need by developing a publicly available specification[79]. A workshop was held with representatives of dismantlers, insurers and repairers to develop an outline specification for a relevant standard. Such a specification (PAS 125) already exists that includes provision for the use of reused body

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[78] Automotive Recycling UK, MVDA, Issue 111 3rd Quarter 2011, p.9

[79] A publicly available specification (PAS) is step towards standardisation based on a consensus driven approach involving the key stakeholders of the sector involved. It provides an agreed framework against which goods and services can be provided

panels. The project did not proceed, however, due to lack of funding for development (approximately £60K).

There are examples of vehicle dismantlers supplying reused parts and components direct to large public sector fleets. A regional police service in England reported a saving of over £100,000 in 2011/12 through the use of reused parts[80]. Discussions with Scottish public sector procurement representatives highlighted that Scottish Local Authorities spend between £7m to £10m on parts to service their vehicle fleets (although a proportion of these will be larger vehicles, such as those used for waste collection). It was estimated that wider Scottish public sector annual spending on vehicle parts could be at least double the local authority figure[81]. Local authorities can arrange their own supply of vehicle parts for their fleets or use suppliers approved under the Scotland Excel „Supply and Delivery of Vehicle Parts' framework. The size of the public sector market represents an opportunity for dismantlers to pursue either directly or via existing framework suppliers.

6.1.2 Material recycling

Metal

Steel in the UK has an indigenous smelting capacity of c6 million tonnes against arisings of c15 million tonnes (implying an export figure of c9 million tonnes). As Scotland is now remote from any UK smelting plant, the likelihood is that steel is exported by ship, either in bulk, or containerised in the case of higher value stainless products.

Figure 39, below, shows the main flows of scrap steel exported from the UK to countries within the EU27 in 2011[82].

Exporters	Jan - Nov		% Change	Biggest Buyers	Jan - Nov		% Change
	2010	2011			2010	2011	
UK	2.114	2.229	+8.4	Spain	1.135	1.099	-3.2
				Portugal	0.275	0.405	+47.3
				France	0.329	0.343	+4.3

Figure 39 - UK internal steel scrap exports to countries within the EU27 (millions tonnes)

Figure 40, below shows the main flows of scrap steel exported from the UK to outside the EU27 in 2011.

80 West Yorkshire Police - http://www.westyorkshire.police.uk/news/national-agreement-secured-disposal-and-recycling-police-vehicles

81 Based on discussions with Scottish public sector procurement representatives

82 „EU 27 Steel scrap statistics on imports/exports and steelwork consumption', European Ferrous Recovery and Recycling Federation, 2012

Exporters	2010	2011	% Change	Biggest Buyers	2010	2011	% Change
UK	5.208	5.376	+3.2	Turkey	1.609	2.087	+29.7
				India	1.287	1.090	-15.3
				Indonesia	0.082	0.315	+284.1
				Egypt	0.761	0.281	-63.1
				China	0.125	0.276	+120.8

Figure 40 - UK steel scrap exports (outside EU27) by country (millions tonnes)

The 2011 total scrap steel exports from the UK to the named „biggest buyers' is 7.6 million tonnes. It is assumed that the remaining 1.4 million tonnes (based on the earlier estimate of 9 million tonnes exported from the UK) is exported in smaller amounts to a wide range of countries.

Batteries

The lead acid battery (LAB) is removed as part of the depollution process. These are then stored in leak proof containers and sold for recycling. Some ATFs check the condition of the battery to ascertain suitability for resale (these usually arise from accident damaged/written off ELV's which maybe only a few months old).

The battery is fully recycled by specialist processors (of which there are around five or six in the UK). The battery is split open, acid removed and the plastic and lead are separated. The plastic and lead is then sold for recycling. The current market value of a scrap LAB is £4 per unit. The ATFs may sell directly to reprocessors or via collectors/aggregators in Scotland. Survey respondents highlighted over 30 different buyers of batteries operating in the Scottish market, highlighting that it is well served.

Catalytic convertors

These are removed from ELVs and sold for recycling to specialist companies (the sale may be through a third party for sorting and grading – 25 buyers of catalytic convertors were identified during the survey of ATFs). These specialist companies know which types of catalytic convertor (CAT) contain the higher value materials such as precious and rare earth metals and, therefore, there are a range of values of each type of CAT.

The final processing company will split open the CAT and remove the contents for further recycling and removal of high value metals. *"In the UK, catalytic converters have been used in all petrol cars since 1993, so increasing numbers of catalytic converters are being recycled. Platinum, rhodium and palladium can be recovered for reuse, and there is a* *good market for this. The ceramic casing can be recovered as a powder for refining"*[83]. Outside casings are sold for metals recycling.

There are a number of specialist purchasers of catalytic convertors in UK. They may grade them for onward sale or some remove inner materials for processing. There is a UK plant that processes spent ELV catalytic convertors but most appear to send material overseas for processing in Europe and the USA.

Electrical components

In addition to electrical components being reused for spare parts they also contain intrinsic value in the materials they contain (mainly copper). These can be sold unstripped or stripped (with the latter achieving a higher value). Several ATFs use copper granulators (or intend to purchase them, according to the survey) to add further value to this material. The material is sold as a commodity through the well-developed scrap metal networks and could be used either in the UK or abroad. The ATFs surveyed identified 13 different buyers of electrical components. These were a mixture of scrap metal businesses and companies operating in the WEEE industry (with one plastics recycler included in the names provided).

Electronic components

Again, electronic components are sold for reuse, refurbishment and remanufacture as a core part. Although they do contain metals with intrinsic material value, discussions with one large WEEE recycler highlighted that sealed components (cased in plastic) can be difficult to extract value from and that they would have to charge a gate fee to accept components such as electronic control units ECUs. Respondents to the survey did, however, identify nine buyers of ELV electronic components operating in Scotland.

During the research for this project, one ATF provided a sample of ECUs to four specialist WEEE reprocessors for evaluation of the commercial viability of extracting valuable materials. One of these reprocessors is currently running a larger scale trial with ECUs following their initial sampling.

Plastics (hard and soft)

Plastics removal for recycling is technically feasible and there are markets for segregated materials such as bumpers and fascia plastics at rates in the order of £60/tonne for baled material (August 2012 prices) and £0 for unbaled. As outlined earlier, however, there is little incentive to input the necessary work to segregate plastics when the scrap ELV hulk value is above the price available for individual products. It is likely, therefore, that, in the absence of increased plastic recyclate prices, decreased prices from the shredders or

[83] „A study to examine the costs and benefits of the ELV Directive. Annex 2: Arisings and Treatment of ELVs – Report to DG Environment', GHK/ Bio Intelligence Services, 2006, p.18

regulatory change, that pre-shredder removal of plastic components will remain a niche for some operators, such as vehicle repairers. There is some activity in this area in Scotland as ten buyers of hard plastic and five buyers of soft plastic were identified during the survey of ATFs. Feedback from industry suggests this activity may be related to plastic parts being removed in the expectation they may be sold for reuse but then being sold for recycling when they fail to do so. Some common plastic types (and associated parts) from ELVs are shown in figure 41, below.

PART	MAIN PLASTICS TYPE	WEIGHT IN AVERAGE CAR (kg)
BUMPERS	PP	10.4
SEATS	PUR, PP, PA, PVC, ABS	18.4
COCKPIT	PP, SMA, ABS, PC, PVC, PUR	21.3
FUEL SYSTEMS	PE, POM, PA	8.6
BODY (including body panels)	PP, PPE, UP	10.8
UNDER THE BONNET COMPONENTS	PA, PP, PBT	13.8
INTERIOR TRIM	PP, ABS, POM, PVC, PUR	31
ELECTRICAL COMPONENTS	PP, PVC, PA, PBT, PE	10.3
EXTERIOR TRIM	ABS, PA, PP, PBT,ASA	5.1
LIGHTING	PP,PC, ABS, PMMA, UP	5.6
UPHOLSTERY	PUR, PP, PVC	6.8
OTHER RESERVOIRS	PP, PE, PA	1.5
TOTAL		143.4

Figure 41 - Location of plastic parts in ELVs[84]

The main source of plastics from ELV is through processing of ASR, rather than separate removal by dismantlers prior to shredding (discussed below and previously). Due to the current lack of ASR processing plants in Scotland then no plastic is separated (post shredder) in Scotland.

Carpet & textiles

Less than 10% of ATFs remove carpet and textiles from ELVs. Only one „trade' buyer of this material was identified during the ATF survey, suggesting that most activity in this area is in spare parts.

Glass

Glass is typically only removed for spare parts as removal for the material itself involves issues with different compositions of glass (toughened and laminated) - *"glass removed*

[84] Commission staff working document accompanying the report on the targets contained in article 7(2)(b) of directive 2000/53/EC on ELV – impact assessment SEC(2007)14, p.48

from ELVs is very hard to recycle because the use of recyclates depends on where the glass was situated in a vehicle. It is impossible to recycle vehicle glass with packaging glass due to specific chemical composition"[85]

Rubber (excluding tyres)

The ATF survey identified 12 buyers of rubber from ELVs operating in Scotland. The market for this material is similar to that for plastic. Further industry feedback suggests that the removal of rubber parts at the dismantling stage will only be carried out if there is a reasonable prospect of the part or component being reused. The sale of rubber material to reprocessors is thought to be related to the disposal of items intended for reuse but which have not sold. The indicative price is similar to plastic (£60 per tonne baled and £0 unbaled). This is not sufficiently attractive compared to the £125 to £175 per tonne paid for ELV hulks by shredders.

Tyres

These are removed from the wheel as the wheel is made of steel or aluminium and can be sold as metal for recycling. The tyre, if it is of a legal quality, can be resold as a "part worn tyre". These tyres must be marked as part worn and any repairs carried out to appropriate British Standards. Feedback from industry suggests around 30% of used tyre arisings from ELV dismantlers are suitable for the part worn market.

The majority of used tyres, which are not suitable for reuse, are removed (for a fee) by tyre collectors who then either bale or shred directly, or a gate fee is paid to have this carried out. An alternative to this is the export of whole legal tyres for reuse or (if not legal) for energy recovery.

In Scotland the majority of end of life passenger and light van tyres are shredded, mainly for use in energy recovery but a small amount goes for use as an equestrian surface material. Most of the energy recovery takes place in Scotland with a small amount of shred being exported for energy recovery. The remaining end of life tyres are baled for intended use in civil engineering projects. For example, civil engineering projects could include the formation of landfill cells or as a lightweight fill material for roads constructed on soft ground. The market for bales is at an early stage of development and more bales are currently being produced than are used.

In addition to the established processes of baling and shredding there are a variety of other technologies and practices being developed in the UK and abroad including: microbial devulcanisation, pyrolysis and cryogenic in addition to size reduction

[85] Commission staff working document accompanying the report on the targets contained in article 7(2)(b) of directive 2000/53/EC on ELV – impact assessment SEC (2007) 14, p.49

technologies. There are also new applications emerging, such as anti-scouring barriers on offshore wind turbines.

Wheels

ELV wheels have an intrinsic material value that is higher than the gate price paid for ELV carcasses by shredders. It is, therefore, economically beneficial to remove them. As with other metal parts, these are sold as a commodity through the well-established network of scrap metal dealers. The ATF survey identified 17 buyers of wheels.

6.2 Markets for shredders

Metal

Metal recovered from shredders is sold as a commodity using the well-established scrap metal industry. The major scrap merchants tend to be located near docks to facilitate the shipping of scrap metal to export markets. Earlier figures 39 and 40 provide details of the key export markets for steel scrap shipped from the UK.

ASR

Scottish based shredders appear to mainly focus any investment on the extraction of metals from ELVs. The residual (ASR) from the end of the process is landfilled at a current cost to shredders of around £68 per tonne and expected to rise to £86 per tonne, in line with the landfill tax escalator, by 2015.

To move to a position of having an indigenous PST industry in Scotland would provide the processing industry with an option with lower transport costs. This would provide options for Scottish shredders to aggregate their ASR for recycling at an economic cost below landfill or the price of transport to facilities in England or elsewhere. Currently, the dedicated shredder residue plants that have been identified have a minimum viable capacity of around 60,000 tonnes to 100,000 tonnes of shredder residue per annum (not ELVs, but the end product from ELV processing after current recycling technology, which includes shredder residue from WEEE). Two of the dedicated shredder residue plants were identified with a minimum capacity requirement of 100,000 tonnes per annum and the capital investment costs of both were approximately £20-25 million. A third plant was identified with a minimum capacity requirement of 60,000 tonnes but no information could be identified on capital cost. As technology develops it may be that minimum capacity requirements and capital investment fall.

An alternative to recycling and thermal recovery of ASR is to use a technology that just uses thermal recovery (with the exception of some recycling of metal fractions from the bottom ash, depending on the system used). During the research for this study, three early stage development projects using plasma gasification were identified. The technology providers behind two of these developments were interviewed and both were confident that a gate fee could be offered to shredders that would be competitive with landfill cost. This potential treatment route for shredder residue has been selected for commercial evaluation in section eight of this report and more detail is provided then.

6.3 Valuable metals and rare earth elements

The recycling of valuable metals has traditionally been a key part of the ELV sector. The valuable metals include:

- Lead - removed mainly at de-pollution stage as batteries come out and wheel weights should be taken off too
- Copper **-** from radiators (although aluminium is also becoming more commonplace), heater matrices, brake pipes and wiring looms. By extension, from starter motors and alternators that have high percentages of copper in their construction, but need further dismantling. The common practice is for onward sale of these items to metal merchants for further treatment or aggregation. Some bigger operators have considered granulation of copper cable or wiring looms, but the capital cost of suitable machinery tends to militate against the higher returns of copper generated
- Catalytic Convertors **–** normally removed at de-pollution stage and dependent on the model, these can be valued at anything from £2 to £80 per unit. They contain platinum, palladium or rhodium. One company in the UK was identified as having smelting and refining facilities for recycling platinum group metals from catalytic convertors. As this company also manufacture catalysts, then it can reasonably be assumed that they then use some or all of the recovered material as an input
- Aluminium – from aluminium alloy wheel, radiators and some engine components
- Engine/gearbox components – these realise a higher value than the lighter steel in a car body. £280/300 (for engines) might be expected rather than the baled/ crushed price of £125 - £175 per tonne. Some ATFs remove these but others don't: this can be a function of the available machinery, with larger operators tending to have machines capable of extracting these components

Rare earth elements are used in a wide variety of consumer electronics, permanent magnets and industrial batteries. An earlier section, 4.2.4, highlighted where rare earth elements are present within ELVs. The markets for them are global and they are in high demand due to export controls from China, which is host to the vast majority of world reserves of rare earth elements[86]. During industry discussions on the potential for

[86] „China faces rare-earth legal challenge', article in Recycling International, April 2012, p. 10

achieving value from rare earth elements, it was noted that there had been reviews carried out by some car manufacturers in relation to the risks to their businesses, in general, and specifically to particular components due to rare earth metal security of supply issues.

One way of alleviating this might be to extract, at the initial dismantling stage, particular rare earth element containing components (e.g. some motor systems/electronic control systems, etc.). Such reverse engineering is likely to require investment in design at the manufacturing stage and in training of the dismantling industry. This is a potential area where the motor vehicle dismantling sector could be trained and encouraged to extract relevant components. This may be a medium-term approach for possible collaboration with vehicle producers and with any eventual signatories to an industry standard dismantling scheme being required to follow such an approach. Alternatively, a regulatory approach may be needed, albeit that this would have to take account of cross-border implications if practices are not replicated across the EU.

7. Medium to long term commercial opportunities

The medium to longer term opportunities, arising from the trends identified in section two, are relevant to the ELV dismantling sector as well as a wider range of businesses with capabilities in financial product development, risk management, logistics and electronics, for example.

In terms of scale of the opportunity it is useful to consider estimates from the recent Ellen MacArthur Foundation report. This report estimates that material cost savings of between USD340 – 630 billion per year in the EU could be achieved by adopting a circular approach in markets for complex durable products, with the motor vehicle sector making the largest savings[87]. This reduction in material use would help mitigate against price volatility and supply risks. It would also reduce externalities including environmental costs of disposal, CO_2 associated with primary extraction, process energy use and process water use. The report further highlights the benefits of this type of approach in the development of local and regional skilled employment to support new business models.

To consider the areas of opportunity in the automotive sector, arising from the medium and long term trends, it is useful to consider a potential future supply chain. The current supply chain was discussed in section two (figure 13). Developing this to reflect anticipated changes of moving towards a „circular economy' model could lead to a future supply chain with the features and characteristics shown in figure 42. This is a simplified representation of a potential future supply chain. Each section of the supply chain will have more intricate relationships within it. For example, a Tier 1 remanufacturer could have Tier 2 and Tier 3 contractors in its supply chain which source, remanufacture and supply components and sub-components, respectively. Each part of the supply chain will have its own process of obtaining used components and sub-components through reverse logistics and related requirements for information, diagnostic and testing equipment, etc. The figure below presents a high level overview of a potential future supply chain to enable the potential opportunities to be better understood and discussed.

[87] „Towards the Circular Economy', Ellen MacArthur Foundation, Vol. 1, Fig 8, p.66, 2012

Automotive sector segment	Supply chain position *OEM Remanufacturer*	*Tier 1 Remanufacturer*	*Independent Remanufacturer*	*OEM contracted refurb, service and repair garage*	*Vehicle Disassembler*
All vehicles (assuming a circular economy model is followed for passenger vehicles/light vans, trucks and buses and heavy plant)	Design for remanufacture Continuous ownership of vehicles Value generated from service fees from consumers Remanufactures vehicles using remanufactured parts and components New vehicle production also uses remanufactured parts and components, where possible Service level agreements for new and remanufactured vehicles Provides information to others in the supply chain about disassembly, quality checking, sub-component sourcing, remanufacture and testing	Obtain cores from vehicle disassemblers, core brokers and OEM contracted refurbishment, service and repair garages Maintains ownership of some key core parts (e.g. batteries) and generates value through service fees from the OEM Supply remanufactured parts to OEM for new vehicle production and vehicle remanufacture Service level agreements for new and remanufactured parts and components Provides information to others in the supply chain about disassembly, quality checking, sub-component sourcing, remanufacture and testing	Focus on core parts not owned by Tier 1 remanufacturers High level of mechatronic skills required Supply to OEMs directly and to OEM contracted refurbishment, service and repair garages Source from vehicle disassemblers and OEM contracted refurbishment, service and repair garages Access information from OEMs and Tier 1 suppliers about disassembly, quality checking, sub-component sourcing, remanufacture and testing	Local refurbishment, service and repair garages contracted to OEMs to ensure vehicles are properly maintained to optimise utilisation Source remanufactured parts and components from Tier 1 and independent remanufacturers Provide used core parts to Tier 1 and independent remanufacturers Once a vehicle can no longer be refurbished or repaired it is passed to vehicle disassemblers Access information on refurbishment, service and repair from OEMs and Tier 1 suppliers	Large volume automated/ semi-automated disassembly plants Source vehicles which are no longer economic to refurbish or repair from OEM contracted refurbishment, service and repair garages Removal of parts and components - cores then go to Tier 1 remanufacturer (if they retain ownership) or to independent remanufacturers (direct or via core brokers) Core vehicle 'skeleton' returned to OEM for use in vehicle remanufacture High level of material segregation for non core elements of the vehicle Zero waste to landfill
Supporting activities	*Finance and risk management* Provision of finance and insurance products to enable OEMs to maintain vehicle ownership and consumers to pay using a service/performance model. Provision of risk management services to support warranties on remanufactured parts and components				
	Consultancy A wide range of supporting consultancy services will be required including: business process; material science; standards accreditation; carbon trading/carbon capture; lifecycle analysis and costing, etc.				
	Education and skills (development and delivery) Development and delivery of training and education for industry on remanufacture and reuse - to develop company specific competencies (existing enterprises and new entrants). Development and provision of wider educational materials for schools, colleges and universities to attract people into reuse, repair, refurbishment and remanufacturing sectors				
	Tool developers Development of specialist diagnostic, processing and testing equipment to support disassembly, service, repair, refurbishment and remanufacturing operations. This will include physical tools/equipment and software tools				
	Reverse logistics (e.g. core brokers) Specialist handling, transportation, storage and supply of core parts from disassemblers and OEM contracted refurbishment, service and repair garages to Tier 1 and independent remanufacturers. Reverse logistics also for core vehicle 'skeleton' back to OEM remanufacturer from vehicle disassemblers				
	Information and Communication Technologies Development and supply/maintenance of ICT systems to enable knowledge sharing amongst different parts of the supply chain about refurbishment, service, repair, disassembly, quality checking of parts/components, sub-component sourcing, remanufacture and testing				
	Repurposing, upcycling and downcycling In addition to reuse, repair, refurbishment and remanufacture of vehicles, parts and components for their original use, there is also a market for repurposing (e.g. Electric car batteries used for wind turbine electricity storage), upcycling (e.g. designers producing consumer goods from parts) and downcycling (e.g. shredding and mechanical separations of parts not suitable for any other purpose)				

Figure 42 - Potential future automotive supply chain based on a move to a circular economy model

The key features and characteristics of a potential future automotive supply chain (by position in the supply chain, including support activities) include:

OEM remanufacturer – Across all types of vehicle, a high proportion of the OEM business relates to remanufacture of vehicles. The OEM retains ownership of the vehicle and, instead of generating revenue through sale of vehicles to consumers, their business model is based on maximising the utilisation of the vehicles through performance/service contracts. The OEM works with financial service companies to facilitate such exchanges. It is, therefore, in the interest of the OEM to design vehicles which are durable, easy to service, repair, refurbish and remanufacture. The remanufacturing process maximises the use of remanufactured parts and components around a core vehicle skeleton (which itself can be remanufactured). New vehicle production also uses remanufactured parts and components, where possible.

Minimum service level agreements are the same for both remanufactured and new vehicles. The OEM contracts with local garages to ensure vehicles are serviced and repaired to ensure service level agreements are met. The OEM also contracts with the local garages to carry out agreed levels of refurbishment to maximise the time between full remanufacture of the vehicle (whilst still meeting the service level agreements with the consumer).

The OEM shares information across the supply chain about all aspects of design (and involves others in the supply chain in new design to optimise functioning at each stage). The information is shared on accessible ICT platforms and covers aspects of disassembly, quality checking, sub-component sourcing, remanufacture and testing.

Tier 1 remanufacturer – The Tier 1 remanufacturer supplies original parts and components to OEM vehicle producers/remanufacturers. In some instances, the Tier 1 remanufacturer retains ownership of some key parts/components and supplies to OEMs under a service level agreement (for example, key parts such as electric batteries, engines, etc.). In this instance the Tier 1 remanufacturer is responsible for ensuring the part provides the agreed performance within the vehicle. They contract directly with local refurbishment, service and repair garages to ensure this level of performance is achieved. Once the part is no longer able to be repaired or refurbished locally it is sent back to the Tier 1 supplier for remanufacture, as they are the legal owner. Tier 1 owned parts and components are also sent back from disassemblers. The Tier 1 remanufacturers work with financial service companies to enable these service level agreements to operate.

New and remanufactured parts and components are supplied to both OEMs (for new vehicle production and vehicle remanufacture) and local garages. Some parts/components may continue to be sold rather than provided under a performance contract. Where this is the case, both new and remanufactured parts/components are supplied with the same warranty.

Tier 1 remanufacturers share information with others in the supply chain and involve other stakeholders in the design process for new parts/components. Information is shared on new ICT platforms which are accessible to all parts of the supply chain and covers aspects of disassembly, quality checking, sub-component sourcing, remanufacture and testing.

Independent remanufacturer – Independent remanufacturers focus on parts and components not owned by Tier 1 remanufacturers. These businesses have significant skills in mechatronics to reflect the prevalence of this technology across a wide range of parts and components.

Independent remanufacturers supply parts and components to OEMs for new vehicle production and vehicle remanufacture. Remanufactured parts and components are also supplied to OEM contracted local refurbishment, service and repair garages. These garages are also a source of supply of core parts, as are vehicle disassemblers. Core parts are sourced directly or via brokers and are restricted to those parts/components where ownership is not retained by Tier 1 remanufacturers.

Information regarding disassembly, quality checking, sub-component sourcing, remanufacture and testing is available to independent remanufacturers via accessible ICT systems. Independent remanufacturers are also involved in the design process for new parts and components in their areas of expertise.

OEM contracted refurbishment, service and repair garage – Refurbishment, service and repair garages have a different customer base, as OEMs and Tier 1 suppliers retain ownership of vehicles and key parts. Instead of generating revenue from end consumers the refurbishment, service and repair garages will contract directly with OEMs and Tier 1 remanufacturers to ensure service level agreements with end consumers are met.

Refurbishment, service and repair garages will source remanufactured parts from Tier 1 remanufacturers and independent remanufacturers. They will also be a provider of core parts to Tier 1 remanufacturers and independent remanufacturers either directly or via core brokers.

Once a garage assesses that it is no longer economically viable to refurbish, repair or service a vehicle it will transfer it to a vehicle disassembler for removal of core parts and materials.

The garages will access information about refurbishment, service and repair from OEMs and Tier 1 suppliers via ICT systems. They will also be involved in the design of new vehicles and parts to optimise refurbishment, service and repair operation.

Vehicle disassembler – Vehicle disassemblers will operate large volume disassembly plants capable of automated and semi-automated operations. As vehicles, and some key parts, are owned by the OEM and Tier 1 remanufacturer the disassembler will have contracts in place to carry out the process and supply core parts (including the vehicle skeleton) back to the owner.

Depending on the arrangements with the OEMs some parts may be supplied to independent remanufacturers, either directly or through core brokers.

The automated nature of disassembly operations means that a higher level of material recovery can be achieved prior to the supply of any end of life parts to downstream material recovery operations. No waste is sent to landfill.

Vehicle disassemblers will have access to information from OEMs and Tier 1 remanufacturers to help optimise the disassembly process. Disassemblers will also be involved in the design of new vehicles and parts with others in the supply chain.

In addition to the different vertical segments in the supply chain, there are a number of supporting activities which will form part of the future supply chain.

Finance and risk management

Companies involved in developing financial and insurance products will work with OEMs and other parts of the supply chain to develop models to enable changes to product service systems. For example, at a vehicle level, this could include financial models to enable OEMs to move from generating revenue from sale of vehicles to a greater use of leasing, sharing, rental, pay-per-use models. At a parts and components level this could involve Tier 1 suppliers retaining ownership of certain parts (e.g. electric batteries) that are leased to OEMs but remain the property of the Tier 1 supplier.

Consultancy

Consultancies with a range of specialities provide support in a number of areas across the supply chain. This includes development of business process systems for existing supply chain players and new entrants. Material scientists and nanotechnologists will provide services to alter material structures to extend life cycles and/or enable easier separation of waste materials at the end of life. Expertise in standards accreditation will be required to support implementation and ongoing auditing of new standards for reuse, repair, refurbishment and remanufacture. Expertise will also be required to quantify, certify and trade the carbon savings made through reuse, repair, refurbishment and remanufacturing operations (compared to carbon emissions associated with new component/part/vehicle production) in response to increasing drivers from carbon related regulation and targets. Consultancies with expertise in life cycle analysis and life cycle costing are also required to provide evidence of wider environmental benefits and lifetime cost savings associated with reuse, repair, refurbishment and remanufacture.

Education and skills

A wide range of nationally/internationally recognised education and skills programmes are developed by the public and private sectors to support increasing demand for a labour force with capabilities in reuse, repair, refurbishment and remanufacture. Company specific training is also carried out by training service providers.

Tool developers

New tools developers provide a wide range of operation specific hand tools and larger physical equipment for disassembly, diagnostic and testing operations. In addition to this a wide range of software tools will be required for diagnostic and testing of increasingly complex mechatronic parts and components.

Reverse logistics

Optimising reverse logistics is a key element in a successful remanufacturing operation. Reverse logistics are required to transport vehicle skeletons, core parts, components and sub-components from vehicle disassemblers and OEM contracted refurbishment, service and repair garages. The destination for these elements is OEM remanufacturers, Tier 1 remanufacturers, independent remanufacturers, component remanufacturers and sub-component remanufacturers. As parts and components develop from mechanical to mechatronic composition, this requires greater expertise in handling, transportation and storage to maintain quality of the different elements.

Information and communication technologies

Enterprises involved in reuse, repair, refurbishment and remanufacture will have access to relevant technical information to support their operations. The flow of this information will be from OEMs and their supply chains to independent remanufacturers, service and repair garages and disassemblers. Information is also transferred in reverse to support future designs of vehicles, parts and components (e.g. to support design for disassembly). The exchange of information is facilitated by new information and communication technologies. Commercial confidentiality barriers have been reduced by regulation (e.g. similar to the International Dismantling Information System developed by vehicle manufacturers in response to legal obligations of the End-of-Life Vehicle Directive).

Repurposing, upcycling and downcycling

Where parts and components are no longer suitable for reuse, repair, refurbishment or remanufacture for their original purpose, alternative uses are found which avoid landfilling of waste. Enterprises are established to repurpose parts and components for use in other applications. For example, the use of electric car batteries where performance has degraded to a level no longer acceptable for a vehicle still has a residual value for use in energy storage for off peak renewable energy generation.

Alternatives to repurposing are upcycling of parts and components into markets where the value created is higher than the original automotive sector value. Frequently upcycling activities involve artists and designers. For example, upcycling end of life seatbelts to produce handbags.

Downcycling of parts and components also has a place in the market where mechanical and/or chemical processes are used to recover materials from parts and components which then have a lower market value than the original automotive sector value. New processes are developed, utilising developments in material science, to lower the cost of recovery.

Summary of commercial opportunities in the medium to long term

There are a number of areas where commercial opportunities may arise (and economic benefits secured) as a result of a move towards the above future supply chain. These include:

1. Development of refurbishment, service and repair operations at the vehicle level (likely to arise in the heavy plant, bus and truck markets before the passenger vehicle/light van market) servicing regional and national markets. These are likely to contract with OEMs and Tier 1 remanufacturers as asset ownership moves from consumer to OEMs and Tier 1 remanufacturers
2. Development of remanufacturing operations at the part, component and sub-component level (with a focus on growth areas of electronic control units, electronic infotainment units and increasing mechatronic components) servicing, regional, national and international markets. Additional focus of these operations could be on remanufacture of parts/components containing high value metals and rare earth elements (e.g. catalytic convertors)
3. Development of large scale, semi-automated, disassembly plants for vehicles no longer suitable for refurbishment, repair and service. These plants will be capable of achieving a high volume of part recovery (for supply as cores) and segregated material recovery (with reducing amounts being sent for mechanical separation with associated residual waste)
4. Development of services around financial instruments to support different business models (e.g. wider use of leasing/pay-per-use models, risk management models to support the availability of refurbished and remanufactured parts and vehicles to others in the supply chain)
5. Development of numerous consultancy services including business process engineering, material science services, standards accreditation, carbon trading/carbon capture (to value the carbon savings made in reuse, repair, refurbishment and remanufacture), lifecycle analysis and life cycle costing (to

provide evidence to consumers of the benefits of changing product service system models)

6. Development and delivery of education and skills training aimed at schools, colleges, universities and businesses (covering elements of reuse, repair, refurbishment and remanufacture)
7. Development of specialist diagnostic, processing and testing equipment to support disassembly, service, repair, refurbishment and remanufacturing operations. This includes physical tools and equipment and also software tools. Enterprises in this area will also have opportunities to supply service and maintenance contracts
8. Development of reverse logistics services taking into account concerns over the increasing need for safe handling, storage and transportation of parts and components with increasing electronic composition
9. Development and maintenance of ICT systems for information sharing between different parts of the supply chain about vehicle and part design, disassembly, quality checking, sub-component sourcing, remanufacture and testing
10. Development of enterprises established to repurpose vehicle components and parts (e.g. electric batteries to renewable energy storage uses)
11. Development of enterprises engaged in upcycling of vehicle parts and components (e.g. artists and designers producing consumer goods)
12. Development of downcycling operations with greater expertise in material recovery (e.g. extraction of rare earth elements from magnetic components)

A number of potential policy actions to support the above medium to long term commercial opportunities are described in section nine.

The above medium to long term opportunities are likely to occur as businesses adopt different business models in response to the medium and long term trends identified earlier. In addition to this there a number of shorter term opportunities which arise mainly due to the need to meet 2015 targets set in the ELV Directive. The following section describes these shorter opportunities and the extent to which they align (or potentially conflict with) the medium and long term opportunities.

8. Short term commercial opportunities

This section provides a description and quantitative comparison of three short term opportunities. The specification of these opportunities was agreed with the project steering group prior to commencement of the modelling.

This section describes the following assessment of short term opportunities:

- Establishment of a spreadsheet based model to compare baseline and models
- Quantification of the economic and environmental impacts of a business as usual scenario
- Modelling and comparison of scenarios which reflect three short term opportunities
  - Post shredder technology recycling and recovery plant
  - ASR plasma gasification plant
  - 50% increase in parts reuse

The first two of the above short term opportunities address the issue of how to recycle and recovery the residual waste from shredding operations in order to meet the 2015 ELV Directive targets. The third opportunity relates to ELV dismantlers achieving a 50% increase in parts recovered and then sold for reuse (without any repair, refurbishment or remanufacture).

The increased reuse of parts from ELV dismantlers is a short term opportunity which aligns well with the medium to longer term opportunities described in the previous section. The capabilities required to remove, categorise and store parts is an important early stage in the subsequent development of more advance disassembly operations.

The other two short term opportunities relate to the mechanical separation and/or energy recovery of mixed residual waste from mechanical shredder and separation plants. It can be argued that this may not be as well aligned with the potential future supply chain described in the previous section. As medium and long term trends lead to higher levels of resource efficiency there will be higher levels of repair, refurbishment and remanufacture of vehicles and parts. In the future supply chain described earlier (figure 42), the emergence of semi-automated vehicle disassembly plants would lead to less material being sent for shredding and sorting. As a result there would be less of a feedstock for automated shredder residue recycling and recovery plant and plasma gasification facilities.

A significant unknown factor in this comparison of short, medium and long term opportunities is the timescales involved in the development of new supply chains. The time taken for new circular economy business models to develop is uncertain. The extent to which pursuing a short term opportunity now might lock the market into energy recovery technologies (at the expense of remanufacture, refurbishment, repair and recycling technologies and practices) is also unknown. It could be argued that over the medium to long term the market pull for recovered parts and components for remanufacture will reduce the flow of material to shredders (and therefore shredder residue to recycling and recovery based treatment facilities). The commercial risk is, therefore, with the shredder facilities and investors in new shredder residue treatment plants. If the move to a circular economy occurs quickly then there is a risk that changes to material flow will occur before investments in shredder residue treatment plants are paid back. If the move to a circular economy takes longer then current investments in new facilities will have time to achieve payback.

It is not obvious, however, that the presence of new shredder residue treatment facilities (which involve part, or all, of the material going to energy from waste) would lock ELV dismantlers into using them to the detriment of market developments in increased reuse, repair, refurbishment or remanufacture of parts and components. ELV dismantlers are highly unlikely to enter into long term agreements to supply shredders. Shredders are also highly unlikely to enter into long term supply contracts with shredder residue treatment facilities. This means that ELV dismantlers should be able to respond to market price signals for additional recovery of parts in the short term. In the medium to longer term, the previous description of the supply chain suggests the emergence of larger scale disassembly plants which are able to economically recovery a greater number of parts and components. If this occurs then the presence of shredder residue treatment plants is unlikely to be a barrier to them pursuing this increased parts and component recovery.

8.1 A model to compare short term opportunities

A spreadsheet based model was developed to enable comparison of short term opportunities. The model is intended to provide baseline data on the number of ELVs arising in Scotland and projections of ELV numbers, weights and material composition to 2030.

The model also projects the number of end-of-life electric and plug-in hybrid batteries. It is available as a separate MS Excel spreadsheet.

8.1.1 Key modelling assumptions

The key aspects of the model include:

- Baseline arisings data
- Future trends in ELV arisings and capture rates
- Trends in hybrid and electric vehicle stock

- Current and projected average vehicle weight
- Current and projected composition
- Recycling and recovery rates
- Gross value and costs
- Environmental impact

The assumptions used in the model are detailed in the remainder of this section.

Baseline arisings data

The model uses baseline information on ELV arisings (based on Certificate of Destruction data) provided by BIS. The 2011 data indicate that 96,717 CODs were issued by Scottish based ATFs.

Future trends in ELV arisings and capture rates

The number of ELVs arriving at Scottish based ATFs in future is likely to be a function of a number of factors:

- The number of new vehicles registered
- The total number of vehicles licensed
- Exports of ELVs from Scotland
- Illegal disposal of ELVs with no COD issued (using operators not registered as ATFs)

Data on the first two of these factors is readily available, as can be seen in figure 43.

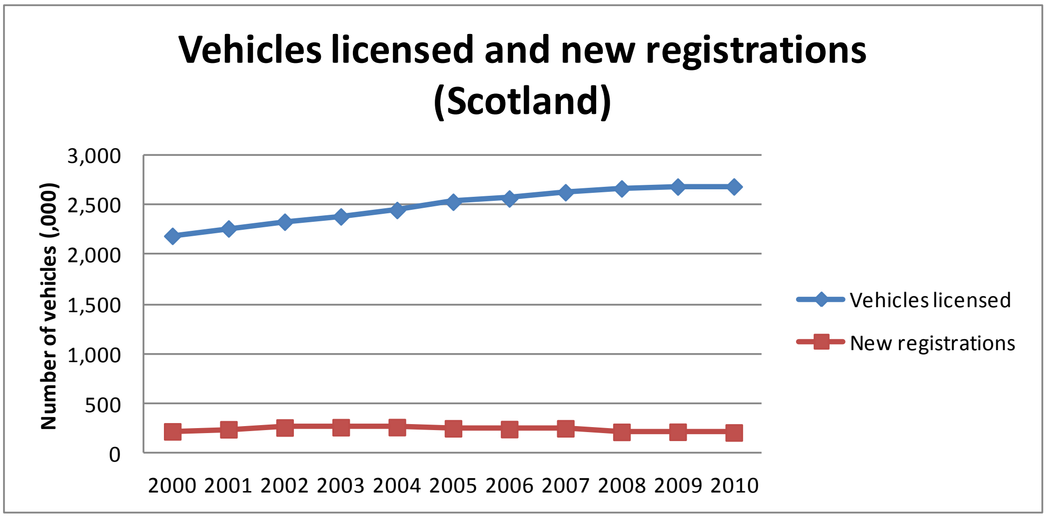

Figure 43 - Trends in vehicles licensed and new registrations in Scotland (2000 to 2010)[88]

The data behind the above figure is shown below:

Year (data in 000's)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Vehicles licensed	2,188	2,262	2,330	2,383	2,448	2,531	2,564	2,627	2,665	2,684	2,685
New registrations	220	241	259	262	263	251	243	251	215	216	209

Figure 44 - Number of vehicles licensed and number of new registrations in Scotland (000's)

Between 2009 and 2010 there were 209,000 new vehicle registrations in Scotland. In the same period, the total number of vehicles licensed in Scotland increased by only 1,000 (calculated by subtracting the 2,684,000 vehicles licensed in 2009 from the 2,685,000 vehicles licensed in 2010, from figure 44, above). It could reasonably be assumed that this equates to 208,000 vehicles being deregistered. This deregistration could occur through dismantling via an ATF, exporting or through treatment via unauthorised operators.

Given that ELV arisings in Scotland in 2009 are (based on the number of CODs issued) estimated to be 110,677 vehicles[89], then one interpretation of the data is that just under 100,000 vehicles (208,000 less 110,677) were exported (as working vehicles) or processed through non-ATF registered channels (e.g. potentially exported as scrap metal without proper ELV depollution processes being carried out).

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88 Transport and Travel in Scotland 2010, Table S1, Scottish Government - http://www.scotland.gov.uk/Publications/2011/08/31092528/9

89 Based on Certificate of Destruction figures provided by BIS – personal communication 28/09/12

Due to the difficulties in identifying the actual capture rates of ELVs, the projection model developed as part of this project assumes no change in the „leakage rate' of ELVs to unauthorised operators. Future ELV arisings are assumed to be correlated to increases in number of new vehicles registered and the baseline for applying these changes will be the 2011 figure of ELVs being processed by ATFs of 96,717 vehicles. Note that the 2010 estimate of ELVs treated is 93,112[90].

A study[91] carried out for the European Environment Agency estimates that, between 2005 and 2030, the number of ELVs arising in EU15 countries is expected to rise by 1.4% p.a. (note this assumes a GDP growth of 1.8% p.a. in GDP). This report highlights that the model does not take into account exports of ELVs and goes on to compare with a similar calculation by the GSK/Bio Services Intelligence report[92] (that includes exporting and covers the period to 2015). This comparison indicates that the medium to long term figure of 1.4% p.a. growth of ELVs may be on the high side as the GHK/Bio Services Intelligence report projects a 2015 ELV arisings figure for the EU that is 11% lower than the former study projected.

In the short term it is also useful to consider recent forecast data on new vehicle registrations in the UK:

- New vehicle registrations in the UK are up by 1.6% in 2012 (compared to 2011) and new vehicle registrations in the UK are up by 1.0% in 2013 (compared to 2012) (forecasts)[93]

New vehicle registrations and ELV arisings are unlikely to be perfectly correlated. The model developed for this project is, for simplicity, based on the assumption that the rate of growth of new vehicle registrations is equal to growth in ELV arisings (in the years where these forecasts exist, i.e. 2012 and 2013). The model also assumes that in the period 2014 to 2030 the growth rate will be less than that used in the GHK/Bio Services Intelligence report. This is based on lower GDP growth rate in the short term and to account for a proportion of ELVs being exported from the UK.

Taking into account the above data and assumptions, the projection model will apply the following annual changes to the 2011 figure of 96,717 ELV arisings in Scotland:

- 2012 – 1.6% increase

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[90] 2010 and 2011 estimates are based on Certificate of Destruction figures for Scotland provided by BIS – personal communication 28/09/12

[91] „Projection of end-of-life vehicles – Development of a projection model and estimates of ELVs for 2005 to 2030', European Topic Centre on Resource and Waste Management (for European Environment Agency), 2008, pp. 18-20

[92] „A study to examine the costs and benefits of the ELV Directive – Report to DG Environment', GHK/ Bio Intelligence Services, 2006

[93] SMMT forecasts UK new car and LCV registrations to 2013

- 2013 – 1.0% increase
- 2014 to 2030 – 1.0% increase (being a lower estimate than the 1.4% referred to above taking into account the lower comparison of the GHK/Bio Services report, which takes into account exports)

Trends in hybrid and electric vehicle stock

A study by [then] BERR and the DfT on the timing and scale of consumer adoption of Electric Vehicles (EV) and Plug-in Hybrid Electric Vehicles (PHEV) can be used as a basis for estimating the number of these types of vehicle in the ELV stream[94].

Various scenarios were presented in this study. The Business As Usual (BAU) scenario is used for the purposes of this report. The BAU scenario assumes that current incentives are left in place with no additional support. Battery costs are such that whole life cost parity with conventional cars would not be achieved until around 2020. Up until this point, growth is limited to congestion zones such as London and amongst green consumers. The model assumes that the rate of adoption in Scotland is the same as the UK. It may be that the actual rate is less in Scotland if the initial growth in EV and PHEV occurs in congestion zones such as London.

Figure 45, below illustrates the gradual increase in adoption in the UK.

	Number of vehicles in UK Car parc			Estimated percentage of overall car parc		
Car type	2010	2020	2030	2010	2020	2030
Total vehicles	29,000,000	32,000,000	35,000,000	100%	100%	100%
EV	3,000	70,000	500,000	0.010%	0.219%	1.429%
PHEV	1,000	200,000	2,500,000	0.003%	0.625%	7.143%

Figure 45 - Projected trends in numbers and percentages of EVs and PHEVs (to 2030)

The part of these vehicles containing most rare earth elements is the battery, which also contains significant amounts of nickel, steel and cobalt (Ni-MH batteries) or lithium, copper, aluminium and cobalt (Li-ion batteries). The projected life-span of batteries is estimated at around 8 years (less that the life of the overall vehicle)[95]. At this stage the options include using the batteries for secondary applications such as storage of off-peak electricity generated from renewables (e.g. solar PV or wind) or recycling via pyrometallurgical or hydrometallurgical processes.

[94] „Investigation into the scope for the Transport Sector to switch to Electric Vehicles and Plug-in Hybrid Vehicles', BERR/DfT, 2008, p.5

[95] „Case study on EV recycling', Recycling International, Spring 2010

To account for the projected 8 year lifespan, the number of batteries from EV and PHEV in the model lags the sales of EV and PHEV by 8 years.

Based on the above assumptions, it is projected that, in Scotland:

- By 2020 there will be approximately 500 EV batteries and 1,700 PHEV batteries reaching end of life for vehicle use p.a.
- By 2025 there will be approximately 650 EV batteries and 2,000 PHEV batteries reaching end of life for vehicle use p.a.
- By 2030 there will be approximately 3,800 EV batteries and 20,000 PHEV batteries reaching end of life for vehicle use p.a.

Current and projected average vehicle weight

The GSK/Bio Intelligence Services report[96] for the EU provides estimates of increasing vehicle weight up to 2015, which is used in the model. This states that average vehicle weights of ELV are:

- 2011 – 1,005kg
- 2012 – 1,010kg
- 2013 – 1,015kg
- 2014 – 1,020kg
- 2015 – 1,025kg

A further reference for the increasing weight of ELVs suggests that the *"weighted average for all car manufacturers show higher weights of ELVs, e.g. of approximately 1,280 kg by 2019 (being the average weight of vehicle put on the market in 2006")*[97].

The model, therefore, shows a straight line increase from 2015 to 2019 to reach the 1,280kg and then remains static thereafter (in the absence of further evidence).

Current and projected composition

Historically, there has been a gradual change in the composition of ELVs: *"It is widely known that the composition of ELVs is changing, in particular an increase in weight of non-ferrous metals and plastics instead of ferrous is expected"*[98]. Figure 46, overleaf, illustrates this trend.

[96] „A study to examine the costs and benefits of the ELV Directive – Report to DG Environment', GHK/ Bio Intelligence Services, Annex 2, Table 9, 2006

[97] Commission staff working document accompanying the report on the targets contained in article 7(2)(b) of directive 2000/53/EC on ELV – impact assessment SEC(2007)14, p.45

[98] *Zoras, A. Et al, „Automotive industry challenges in meeting EU 2015 environmental standard", Technology in Society 34(2012) pp. 55-83*

Material	Vehicle 1 (%)	Vehicle 2 (%)
Ferrous metals	71.5	65.4
Non ferrous metals	6.8	10.0
Rubber	5.0	5.6
Fluids (not including fuel)	2.0	2.0
Plastics	8.0	9.3
Glass	2.9	2.9
Others	3.9	4.8

Figure 46 - Average material compositions of vehicles produced in 1985 (Vehicle 1) and 1998 (Vehicle 2)[99]

Projecting forward, this trend is assumed to continue, based on the data in figure 47, below.

Material/Component	2003 ELV (% by weight)	2015 ELV (% by weight)
Ferrous Metal	68%	66%
Non Ferrous Metal	8%	9%
Plastics and Process Polymers	10%	12%
Tyres	3%	3%
Glass	3%	2%
Batteries	1%	1%
Fluids	2%	2%
Textiles	1%	1%
Rubber	2%	2%
Other	2%	2%
Total	100%	100%

Figure 47 - Typical composition of a 2003 ELV and a 2003 new vehicle (and therefore a 2015 ELV) by weight, UK[100]

The model assumes the following composition for 2011 projections:

- Ferrous metal – 66.8%
- Non-ferrous metal – 8.6%
- Plastics – 11.2%
- Tyres – 3%
- Glass – 2.4%
- Batteries – 1%
- Fluids – 2%

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[99] Ferrao, P. et al, „Assessing the economics of auto recycling activities in relation to EU Directive on End of Life Vehicles', Technological Forecasting and Social Change 73 (2006) pp. 277-289

[100] Commission staff working document accompanying the report on the targets contained in article 7(2)(b) of directive 2000/53/EC on ELV – impact assessment SEC(2007)14, p.7

- Textiles – 1%
- Rubber – 2%
- Other 2%

This increases gradually to the 2015 data in the above figure. No evidence was identified for any subsequent changes in composition post 2015 and, therefore, the data, remains static to 2030.

Recycling and recovery rates

The following figure shows the assumed reuse, recycling and recovery rates by material from a typical vehicle. The source study developed different scenarios for total reuse, recycling and recovery and this report uses the „advanced standards of ELV treatment' that achieves a rate of 83.5%[101]:

Material/Fraction	Kg				
	Reuse	Recycling	Recovery	Landfill	Total
Ferrous metal	31	611	0	8	650
Non ferrous metal	9	79	0	2	90
Plastic	1	11	12	96	120
Tyres	10	10	10	0	30
Glass	1	14	0	15	30
Batteries	1	12	0	0	13
Fluids	5	12	0	0	17
Textiles	0	1	0	9	10
Rubber	0	5	0	15	20
Other	0	0	0	20	20
Total (weight)	58	755	22	165	1000
Total (%)	5.8%	75.5%	2.2%	16.5%	100.0%
Reuse and recycling (%)	81.3%				
Reuse, recycling and recovery (%)	83.5%				

Figure 48 - Baseline treatment rates by material/fraction

The 83.5% overall reuse, recycling and recovery rate is consistent with the 2009 data for the UK found in the Eurostat database[102] (with the reuse and recycling rate being 82.1%). The equivalent data for 2010 is 85.6% for reuse, recycling and recovery (with 83% reuse

101 „A study to examine the costs and benefits of the ELV Directive – Report to DG Environment', GHK/ Bio Intelligence Services, 2006, Table 5.5, p.74

102 Eurostat ELV data – http://epp.eurostat.ec.europa.eu/portal/page/portal/waste/key_waste_streams/end_of_life_vehicles_elvs

and recycling). This data shows an increase in overall reuse, recycling and recovery rate of 2.1% (1.2% coming from recovery and 0.9% from reuse and recycling).

The increase in reuse, recycling and recovery rates in the UK are assumed to be driven by developments in Post Shredder Technology in plants based in England. The rates in figure 48 are, therefore, used as a baseline performance for Scotland in the model developed as part of this project.

Gross values and costs used in the business as usual scenario

The following estimates of values and costs associated with ELV treatment are used in the modelling of the „business as usual' scenario. These estimates have been established following discussions with the ELV dismantling and shredding industry and material reprocessors.

1. Average value achieved from component and parts reuse = £100 per vehicle
2. Income received from reuse of ferrous metal is already included in component/parts revenue
3. Recycling of ferrous metal attracts an average income of £260 per tonne
4. Income received from reuse of non ferrous metal is already included in component/parts revenue
5. Recycling of non ferrous metal attracts an average income of £1,000 per tonne
6. Income received from reuse of plastics is already included in component/parts revenue
7. Recycling of baled plastics (e.g. bumpers) attracts an income of £60 per tonne. Other feedback from the industry suggests that if bumpers are not baled they may be uplifted free of charge by plastic reprocessors. The model uses a figure of £30 to reflect the mix between baled and loose plastic. Given that this is less than the price that could be achieved if left in the vehicle for shredding it is assumed this occurs where plastic parts have been removed for resale but this has not been achieved
8. Recovery of plastics predominately occurs where plastic components attached to engines and gearboxes are sent for smelting and the plastic self fuels part of the smelting process. In this situation the plastic parts are assumed to achieve a value of £300 per tonne, which is an estimated value for engines sent for recycling (where the plastic parts are part of the overall engine weight). The model assumes that 10% of plastic recovered is through the smelting of engines and gearboxes and, therefore, the model uses a figure of £30 applied to total weight of plastics classed as recovered

9. Tyre disposal costs to the dismantler (regardless of whether they are reused, recycled or used for energy recovery) are assumed to be £0.75 per tyre
10. Income received from reuse of glass is already included in component/parts revenue
11. Income from glass recycling is assumed to be associated with the use of glass as an aggregate. The aggregate would be a fine fill material that is assumed to be provided free of charge
12. Income received from reuse of batteries is already included in component/parts revenue
13. Income from battery recycling is based on the value of the metal contained in the battery (predominately lead from lead-acid batteries). This is already taken account of in the income from metal. The weight attributed to battery recycling is based on the average non-metallic element of 4kg per battery. It is assumed that no additional income is obtained from this material by the dismantler as they are paid for the metal content
14. Income from the reuse and recycling of fluids is assumed to be zero as many waste management companies offer to take all fluids along with contaminated rags for free from the dismantlers
15. Income from textile recycling is estimated at £10 per tonne based on discussions with textile recyclers (which indicated that there are limited markets for this type of material). Given that this is less than the price that could be achieved if left in the vehicle for shredding it is assumed that this occurs where parts containing textiles have been removed for resale but this has not been achieved
16. The income from (non-tyre) rubber recycling is assumed to be similar to that achieved for plastics, i.e. £30 per tonne. Given that this is less than the price that could be achieved if left in the vehicle for shredding it is assumed that this occurs where parts containing rubber have been removed for resale but this has not been achieved
17. Landfill for ASR – the fines and light fraction are currently used as a daily cover material and, therefore, attracts a minimal gate fee and the overall cost is mainly to cover the Landfill Tax. As Landfill Tax increases in April each year the following rates have been adjusted to apply to a calendar year in the model:

Landfill Tax Year	Tax	Est. gate fee	Total fee	Model Year	Average annual charge
2011/12	£56	£6	£62	2011	£60
2012/13	£64	£6	£70	2012	£68
2013/14	£72	£6	£78	2013	£76
2014/15	£80	£6	£86	2014	£84
2015 onwards	£80	£6	£86	2015	£86

Figure 49 – Estimated annual landfill charge (tax + gate fee) for ASR disposal

18. No account has been made for any further rises in landfill tax or changes to the ability of landfill operators to use ASR as capping material. Similarly the model assumes no changes to commodity prices or other disposal costs.

Environmental impact

The environmental impact of baseline and alternative scenarios will be calculated using the following „per tonne' data from figure 50, below.

Material/Fraction	% of ELV Weight landfilled	Env. Benefit Recycling, £/t	Env. Benefit Thermal Energy Recovery, £/t
Ferrous metal	0.8	80.73	80.73
Non ferrous metal	0.2	507.7	507.7
Plastic	9.6	82.36	-97.21
Tyres	0		
Glass	1.5	16.74	0
Batteries	0		
Fluids	0		
Textiles	0.9	163.42	-56.43
Rubber	1.5	82.36	-97.21
Other	2		
Total	**16.5**		

Figure 50 - Unit Environmental Benefits from Recycling and Thermal Treatment with Energy Recovery (£ per tonne waste) Positive Value means a Benefit[103]

The environmental cost/benefit of scenarios where material is diverted from landfill (to either recycling or thermal recovery) is calculated using the above data. The environmental benefits of reuse were not quantified in the source report due to lack of available data. The environmental benefits of reuse are, therefore, not included in this analysis beyond a stated reduction in weight of material sent to landfill. It should also be

[103] Based upon „Producer Responsibility: Policy Evaluation – Final Report to the Scottish Government', Eunomia, 2011, Table 10-6, p. 127

noted that the positive values used for energy recovery of ferrous and non ferrous metal assumes that the metal is recovered from the ash and then recycled.

8.1.2 Model limitations

A necessary step in developing any model is to simplify what actually occurs in reality. This has resulted in the model having a number of limitations, including the following:

1. The reuse, recycling and recovery rates used are based on UK wide data for 2009. It has been assumed that the Scottish rates for 2011 are consistent with this due to limited non-metallic PST investment in Scotland. The exact rates are unknown and this creates uncertainty in the projections
2. The baseline assumptions of ELVs treated use data on Certificates of Destruction issued. There is considerable uncertainty associated with this approach as significant numbers of vehicles are likely to have been processed without Certificates of Destruction being issued
3. The model only includes costs associated with disposal of tyres and residual material to landfill. It does not include either capital investment costs or other operating costs of different scenarios. These are considered separately when comparing the various scenarios
4. Historical patterns suggest that commodity material prices fluctuate significantly over time due to global economic supply and demand issues. The model uses constant prices and, as such, introduces potential error into the outputs
5. The value achieved through parts and components reuse is stated as an average per ELV. The range around this value is significant depending on the type of vehicle. The average figure is based upon a mix of vehicles that may or may not be representative of the overall mix of ELVs present in Scotland
6. The cost associated with landfilling materials remains constant after 2015. It is likely that the decreasing supply of landfill capacity will lead to an increasing market-driven landfill cost. In addition to this, there may also be further changes in cost due to further increases in landfill tax
7. No account has been taken of the costs and potential value of recovery of rare earth metals in future. This was due to the lack of commercially feasible operations from which costs could be obtained. The recovery of rare earth metals is likely to be of increasing importance and by 2030 it is possible that more focus will be given to rare earth containing components within ELVs
8. The values used for the sale of recycled ferrous and non ferrous metal are also used for the sale of metal recovered from bottom ash after thermal treatment. It

is likely that this metal would be regarded as lower quality and, therefore, attract a lower price

9. The changes to the reuse, recycling and recovery rates for scenarios 1 & 2 (from the business as usual rates) are estimates made due to lack of information about the actual rates achieved by different technologies. This information is commercially sensitive and the operators were not willing to divulge this detailed breakdown. These estimates are a potential source of error in the model projections
10. Scenario 3 considers an increase in 50% of the value of reused parts and components compared to business as usual. The model assumes that the 50% increase in value is matched by a 50% increase in weight of parts and components reused. If this is not the case then error is introduced to the model which assumes an associated fall in material recycling when reuse increases

8.2 Outcomes of a Business as usual scenario

The business as usual scenario assumes no further processing investment or changes to business practice amongst Scottish based dismantlers and shredders. The treatment rates shown in figure 48 are assumed constant until 2030. Under this scenario the following values (including disposal costs, shown as a negative) are achieved.

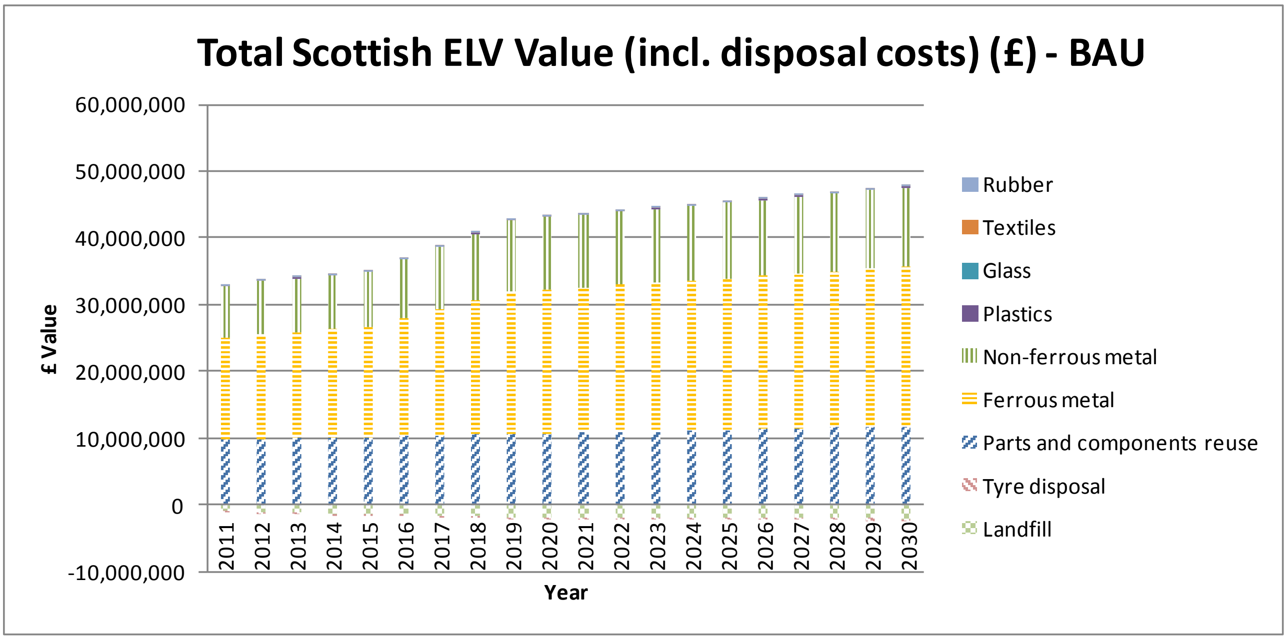

Figure 51 - Total Scottish ELV Value (incl. disposal costs) (£) from 2011 to 2030

In 2011 the total value of ELVs processed in Scotland (net of landfill and tyre disposal costs) is estimated to be almost £32 million. By 2030, this is projected to increase to over

£45 million. The net value of an average end of life vehicle in 2011 is estimated to be £327 rising to £385 by 2030 (mainly due to projected increases in average vehicle weight). This value is shared between the final owner of the vehicle, the dismantler and the shredder company.

The main element of value is achieved from income from ferrous metal sales, with income from non ferrous metal being the second largest contributor to total value. Parts and components reuse are the other significant contributor to total value.

Based on these estimates, it is possible to quantify the impact of ELVs being treated by unauthorised operators. For every 1,000 ELVs being treated by unauthorised operators the value lost to the dismantling and shredding sector is £327,000. There are several impacts of this lost value:

- Undermines confidence and ability of the industry to invest
- Leakage of value on a national level due to illegal operations more likely to avoid tax payments
- Greater environmental costs due to lack of proper de-pollution and disposal processes

A significant amount of material is sent to landfill. The model estimates that just over 16,000 tonnes of ASR was sent to landfill in 2011. An estimate based on discussions with the four main ELV shredders in Scotland (combined with data from SEPA in some cases) was around 20,000 tonnes of ASR. This difference suggests that the actual reuse, recycling and recovery figure in Scotland is less than the UK average (less than 80% on this basis) and that the data in the model underestimates the amount of ASR landfilled. Another factor that may account for this difference is that the shredders are likely to be processing some ELVs that were not issued a Certificate of Destruction. It should again be noted that shredders process other metal containing products (e.g. WEEE) and that total shredder residue (including ASR) in Scotland is estimated to be around 60,000 tonnes per year.

An estimate of the environmental impacts of the recycling and recovery of ELVs can be made. No data are available to enable calculation of the environmental benefits of parts and components reuse so these have not been considered. Note that no environmental benefit has been apportioned to glass recycling as it is assumed to go to aggregate use.

Figure 52, overleaf, shows the estimated environmental benefits from material recycling and recovery from ELVs in Scotland.

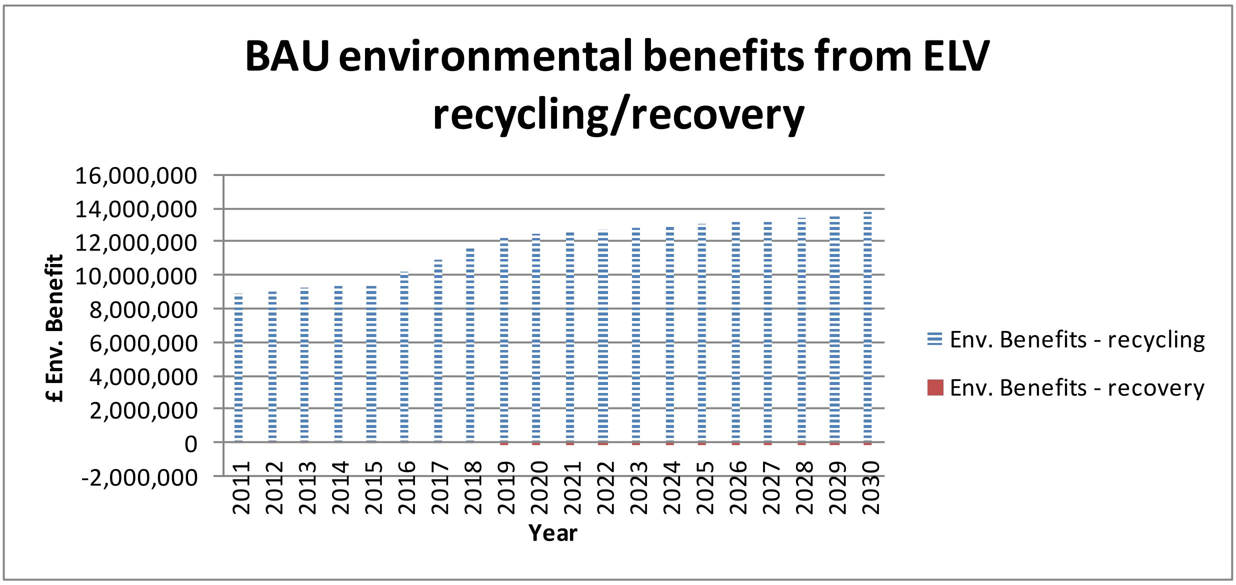

Figure 52- Environmental benefits from ELV recycling and recovery

The estimated net environmental benefit of material recycling and recovery from ELVs in Scotland is almost £9 million for 2011. The relatively minor environmental cost is due to plastic being thermally recovered as part of the smelting process (for engines, gearboxes, etc.). The net environmental benefit is projected to increase to over £13.5 million in 2030.

Adding the estimated economic value to the environmental benefits suggests that the true social benefit from ELV treatment in Scotland is over £41 million in 2011 rising to almost £59 million in 2030. This equates to social benefits per ELV of £417 in 2011 and £500 in 2030.

8.3 Comparing different short term opportunities

Based on feedback from industry and discussions with other stakeholders, a number of commercial opportunities have been identified for further analysis. The economic and environmental impacts of these scenarios are then compared against the business as usual scenarios. The scenarios investigated are:

- Scenario 1 – Post Shredder Technology plant
- Scenario 2 – ASR plasma gasification plant
- Scenario 3 – 50% increase in parts reuse

Each of these is now discussed in detail.

8.3.1 Scenario 1 – Post Shredder Technology plant

A number of shredders in Scotland have invested in Post Shredder Technology (PST) to improve recovery rates of ferrous and non-ferrous materials. Others send ASR to third party material recovery facilities for materials to be extracted prior to landfill. The latter process involves the material being processed through hand picking lines to extract metal.

At least three PST plants have been established in England and a significant number in Europe (see earlier section 4.2.3). Approximate investment costs and minimum capacity requirements were identified for two plants. The estimated investment costs are between £20 million and £25 million and the minimum capacity required is between 60,000 tonnes to 100,000 tonnes per annum. If it is assumed that the additional shredder (from processing of WEEE scrap) that is available from the four major shredders is around 40,000 tonnes (based on a combination of shredder feedback and SEPA returns) then the total (60,000 tonnes of shredder residue) is at the lower end of minimum commercially viability. This information about the current commercially viable scale of this type of operation suggests that (based on this current technology) there is an issue with sufficient shredder residue arisings (as at the lower end of commercial viability all the Scottish shredder arisings would be required – leaving the PST plant operator commercially exposed). The model has been developed to demonstrate the scale of the potential economic and environmental benefit, relative to other scenarios.

The existing PST plants identified generate revenue from recovered material sales and face costs associated with material disposal. The estimated values used in the model projections, which differ from those in the business as usual scenario are:

- Plastic ~ £300 per tonne[104]
- Solid recovered fuel (SRF) sales ~ £31 per tonne[105]

The key assumptions about changes in this scenario compared to the business as usual scenario are:

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[104] Based on industry feedback on price for granulated bumper plastic

[105] Straetmans, B. „SRF Market Views in Europe', International Workshop on SRF, 2010, European Recovered Fuel Organisation – Potential value for SRF meeting CEN TC 343 in use for co-processing in cement plants and/or co-firing in coal power plants

Material/Fraction	% of total ELV landfilled under BAU	New assumptions for Scenario 1		
		% of total ELV extracted for recycling	% of total ELV used as SRF (recovery)	% of total ELV sent to landfill
Ferrous metal	0.8	0.4		0.4
Non-ferrous metal	0.2	0.1		0.1
Plastics	9.6	4.5	2.9	2.2
Tyres	0			
Glass	1.5	1		0.5
Batteries	0			
Fluids	0			
Textiles	0.9		0.6	0.3
Rubber	1.5		1	0.5
Other	2	0.2	0.8	1
Total	**16.5**	**6.2**	**5.3**	**5**

Figure 53 - Assumed changes for scenario 1 compared to the BAU scenario

Given the commercial sensitivity of the actual outputs achieved by ASR processes, it has been necessary to estimate the changes to the business as usual scenario. It has been assumed that 50% of ferrous and non-ferrous metal, currently landfilled, is recycled with the remaining 50% still being sent to landfill (being trapped in small fractions with other material and not being economically viable to separate). Proportions of other materials continue to be landfilled to a level of 5%, meaning that this scenario is consistent with achieving the 95% recycling and recovery target of the ELV Directive. The SRF produced as part of the treatment is assumed to contain fractions of plastic (with minimal residual PVC), textiles, rubber and other material.

Given an estimated investment, planning and build time of two years, it is assumed that the overall reuse, recycling and recovery rate will reach 95% by 2015.

The overall economic value of ELV materials and disposal costs are shown in figure 54, overleaf.

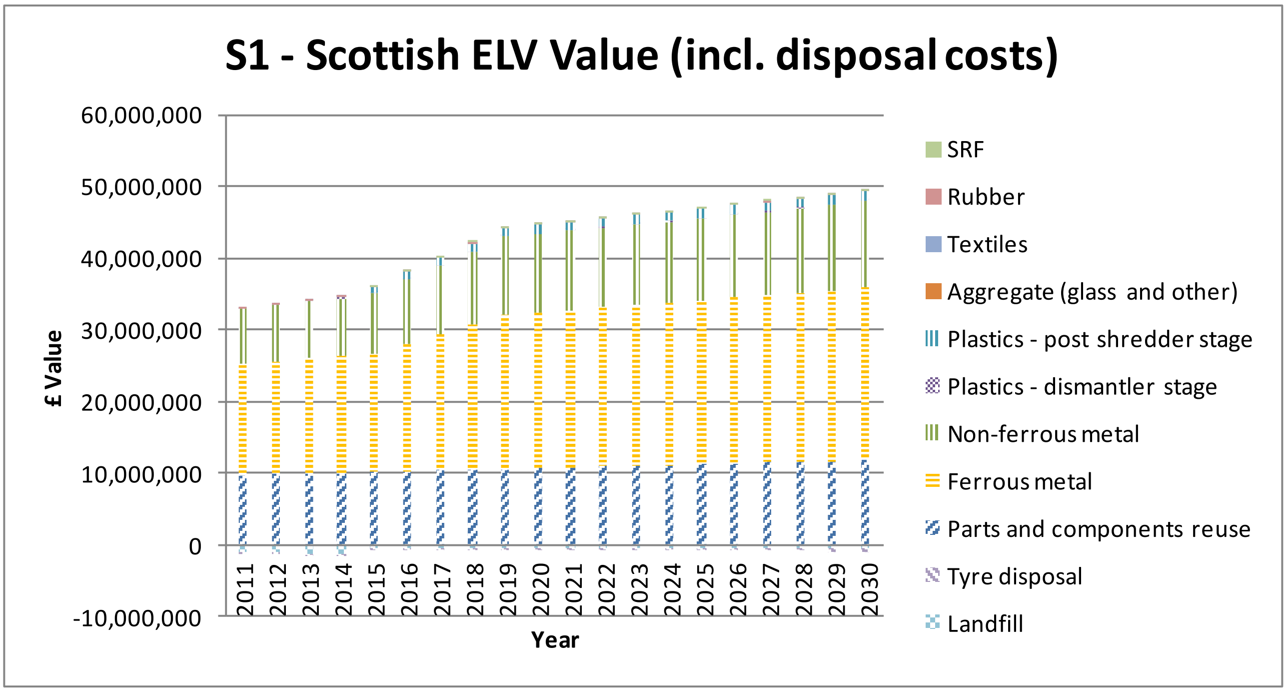

Figure 54 - Scenario 1 – Post Shredder Technology plant – material value and disposal costs

The model projections show an overall economic value of ELV materials (net of disposal costs) of almost £32 million in 2011. In 2015 there is change from the business as usual scenario when more value is recovered from metal and plastic with a reduction in material sent to landfill. By 2030 the model projects an overall economic value of ELV materials (net of disposal costs) of nearly £47 million. Considering this scenario from an individual ELV perspective, the economic value (net of disposal costs) changes from £327 in 2011 to £413 in 2030.

As with the business as usual scenario, the overall environmental impact of material recycling and recovery can be projected. Figure 55, overleaf, shows the environmental benefits of recycling and the costs of recovery expressed in economic terms. As with the business as usual scenario, this does not include the environmental benefits of reuse as no data was identified to enable this calculation to be made.

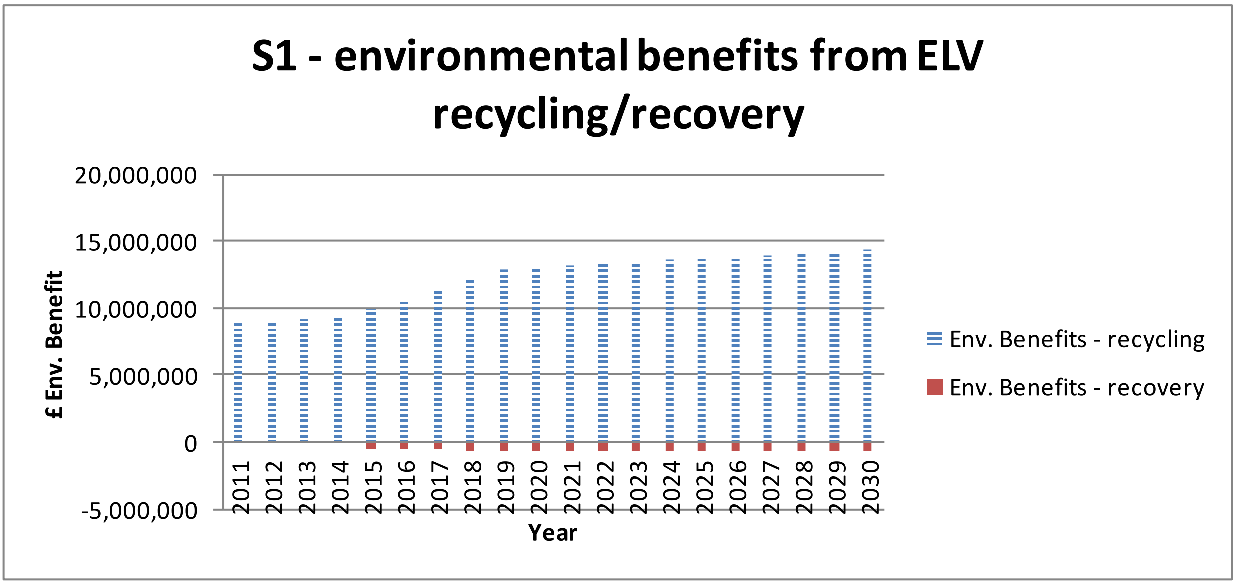

Figure 55 - Scenario 1 – Post Shredder Technology plant – environmental benefits and costs

The net environmental benefit of ELV recycling and recovery in Scotland was almost £9 million in 2011. This is projected to increase to nearly £14 million by 2030. There is a noticeable increase in environmental costs from 2015 onwards associated with the use of plastic material in SRF production and use.

The environmental benefit can also be expressed in terms of an individual ELV. In 2011, each ELV treated resulted in environmental benefits equivalent to £90. This is projected to rise to £115 by 2030. These figures are the same as the business as usual case due to the additional environmental benefits of material being recycled are cancelled out by the additional environmental costs of the material being recovered via thermal treatment.

Considering both the economic and environmental values and costs together results in an overall social benefit to Scotland of ELV recycling and recovery of £41 million in 2011, projected to rise to £62 million by 2030. The equivalent figures at an individual ELV level are £317 social benefit in 2011 rising to £528 in 2030.

8.3.2 Scenario 2 – ASR plasma gasification plant

An alternative to scenario 1 (PST Technology plant) is the treatment of ASR via plasma gasification. Unlike scenario 1, which involved a plant dedicated to recycling and recovery of ASR, a plasma gasification plant can treat a wide variety of waste feedstocks. The process generates a synthetic gas (syngas) that can be used to generate heat and power by feeding a combined heat and power plant. Some systems can recover metal fractions before the residue is vitrified to an inert, „glass-like', material that can be used as an aggregate. The technology has been proven in the treatment of ASR in other countries, such as Japan. Discussions with two companies supplying this type of plant suggest that a minimum commercially viable operation would be in the region of 50,000 tonnes per annum. This compares to estimated total shredder residue (from both ELV and WEEE) in Scotland of around 60,000 tonnes per annum. As previously stated, mixed feedstocks can be used with this technology.

The indicative investment cost is thought to be around £20 million with modularised development possible (in 50,000 tonne modules).

Compared to MSW incineration, this technology uses relatively less air in the combustion process meaning relatively less emissions. In the absence of any alternative data, the model uses environmental impact conversion factors based on MSW incineration. This is likely to produce environmental costs that are higher than would actually result from the plasma gasification technology (although no alternative reference source could be dentified).

During the research process, three merchant facilities using plasma gasification technology (at various early stages of planning) were identified in Scotland. At least one of these has already approached producers of ASR with a view to investigating the material as a potential feedstock.

The estimated values used in the model projections, which differ from those in the business as usual scenario are[106]:

- Income from electricity generation - £150 from each tonne of ASR
- Income achieved from vitrified residue used as aggregate - £0

The key assumptions about changes in this scenario compared to the business as usual scenario are:

[106] Values estimated through discussions with two technology suppliers/operators. The zero value of the residue as an aggregate is viewed as a conservative estimate

Material/Fraction	% of total ELV landfilled under BAU	New assumptions for Scenario 2 % of total ELV extracted for recycling	% of total ELV used in Plasma (recovery)	% of total ELV recoverd as aggregate
Ferrous metal	0.8		0.4	0.4
Non-ferrous metal	0.2		0.1	0.1
Plastics	9.6		9.6	
Tyres	0			
Glass	1.5			1.5
Batteries	0			
Fluids	0			
Textiles	0.9		0.9	
Rubber	1.5		1.5	
Other	2		1.5	0.5
Total	**16.5**	**0**	**14**	**2.5**

Figure 56 - Assumed changes for scenario 2 compared to the BAU scenario

Scenario 2 assumes no recycling of materials prior to thermal treatment. It is assumed that 50% of the ferrous and non ferrous metal is recovered from bottom ash prior to it being vitrified. In this scenario there is no material residue to landfill.

Given an estimated investment, planning and build time of two years, it is assumed that the overall reuse, recycling and recovery rate will reach 100% by 2015. This assumes that the efficiency of the CHP operation is sufficient to be classed as recovery.

The overall economic value of ELV materials and disposal costs are shown in figure 57, overleaf.

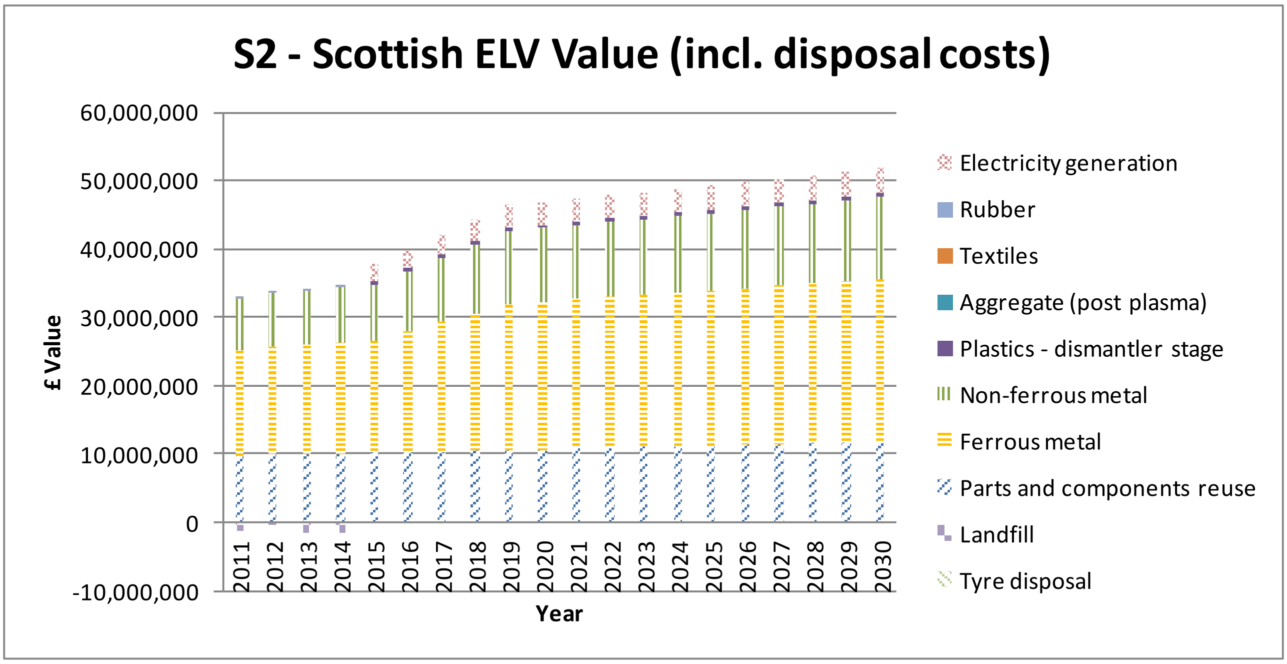

Figure 57 - Scenario 2 – ASR plasma gasification – material value and disposal costs

The model projections show an overall economic value of ELV materials (net of disposal costs) of almost £32 million in 2011. In 2015 there is change from the business as usual scenario when more value is projected from electricity generation, with a reduction in material sent to landfill to zero. By 2030 the model projects an overall economic value of ELV materials (net of disposal costs) of over £451 million. Considering this scenario from an individual ELV perspective, the economic value (net of disposal costs) changes from £327 in 2011 to £438 in 2030.

As with the business as usual scenario, the overall environmental impact of material recycling and recovery can be projected. Figure 58, overleaf, shows the environmental benefits of recycling and costs of recovery expressed in economic terms. As with the business as usual scenario this does not include the environmental benefits of reuse as no data was identified to enable this calculation to be made.

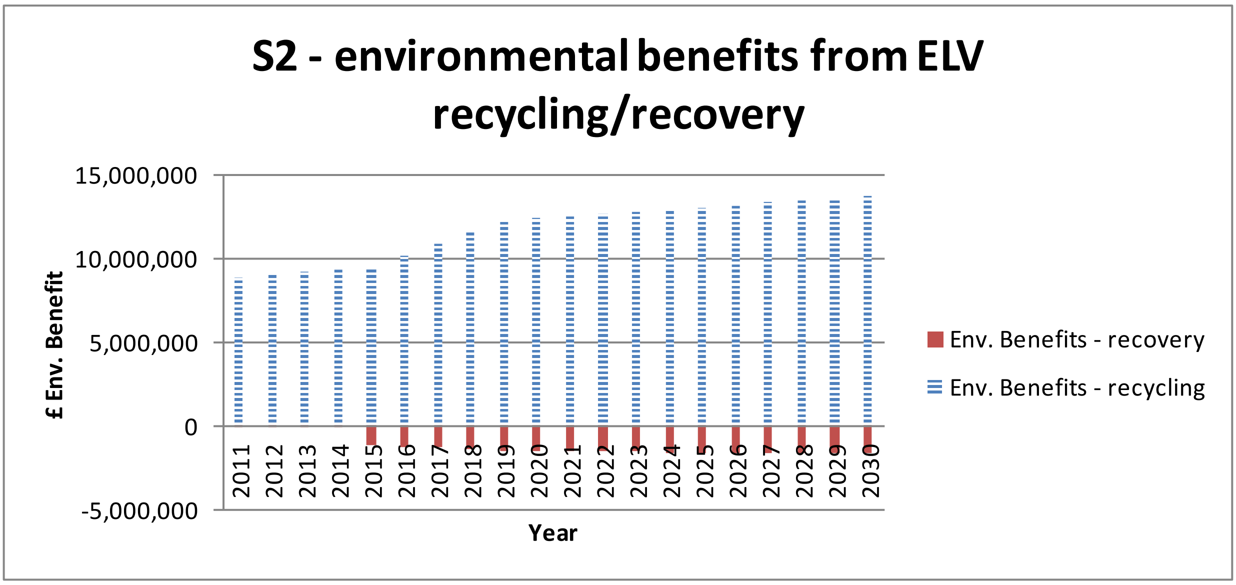

Figure 58 - Scenario 2 – ASR plasma gasification – environmental benefits and costs

The net environmental benefit of ELV recycling and recovery in Scotland was almost £9 million in 2011. This is projected to increase to nearly £12 million by 2030. There is a noticeable increase in environmental costs from 2015 onwards associated with the thermal treatment of the ASR.

The environmental benefit can also be expressed in terms of an individual ELV. In 2011, each ELV treated resulted in environmental benefits equivalent to £90. This is projected to rise to £101 by 2030.

Considering both the economic and environmental values and costs together results in an overall social benefit to Scotland of ELV recycling and recovery of £41 million in 2011, projected to rise to £73.4 million by 2030. The equivalent figures at an individual ELV level are £417 social benefit in 2011 rising to £539 in 2030.

8.3.3 Scenario 3 – 50% increase in value of parts reuse

The third scenario involves a 50% increase in the value achieved from the reuse of parts and components at the dismantler stage. The business as usual scenario assumes an average income from this source of £100 per ELV. The value in scenario 3 is assumed to be £100 until 2013, £125 in 2014 and £150 per ELV from 2015 onwards. All other values remain the same as in the business as usual scenario. The weight of the ELV, which is assumed to be reused, increases from 5.8% to 8.7% over the period 2013 to 2015. The impact of this 2.9% increase in parts and components reuse on the recycling, recovery and landfill rates is shown in figure 59, overleaf.

Material/Fraction	% Reuse		% Recycling		% Recovery		% Landfill		Total	
	BAU	S3	BAU	S3	BAU	S3	BAU	S3	BAU	S3
Ferrous metal	3.1%	5.1%	61.1%	59.1%	0.0%	0.0%	0.8%	0.8%	65.0%	65.0%
Non-ferrous metal	0.9%	1.2%	7.9%	7.6%	0.0%	0.0%	0.2%	0.2%	9.0%	9.0%
Plastics	0.1%	0.4%	1.1%	1.1%	1.2%	1.2%	9.6%	9.3%	12.0%	12.0%
Tyres	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%	0.0%	0.0%	3.0%	3.0%
Glass	0.1%	0.3%	1.4%	1.4%	0.0%	0.0%	1.5%	1.3%	3.0%	3.0%
Batteries	0.1%	0.1%	1.2%	1.2%	0.0%	0.0%	0.0%	0.0%	1.3%	1.3%
Fluids	0.5%	0.5%	1.2%	1.2%	0.0%	0.0%	0.0%	0.0%	1.7%	1.7%
Textiles	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.9%	0.9%	1.0%	1.0%
Rubber	0.0%	0.1%	0.5%	0.5%	0.0%	0.0%	1.5%	1.4%	2.0%	2.0%
Other	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.0%	2.0%	2.0%	2.0%
Total	5.8%	8.7%	75.5%	73.2%	2.2%	2.2%	16.5%	15.9%	100.0%	100.0%

Figure 59 - Assumed changes in rates of recycling, recovery and landfill as a result in increases in reuse

The above figure shows the assumed changes to recycling, recovery and landfill resulting from an increase in parts and components reuse. Recent experience of a pilot in England, involving a number of dismantlers supplying retail service and repair garages, suggested that demand tended to be for items such as glass, bumper mounts, washer bottles, trims and seals (items with high glass, plastic and rubber contents)[107]. The assumed change in material, therefore, includes metal (shifting from recycling to reuse), plastics (shifting from landfill to reuse), glass (shifting from landfill to reuse) and rubber (shifting from landfill to reuse). It should be noted that the reuse of parts and components is finite and the eventual treatment may still include landfill.

The overall economic value of ELV materials and disposal costs are shown in figure 60, overleaf.

[107] Automotive Recycling UK, MVDA, Issue 111 3rd Quarter 2011, p.9

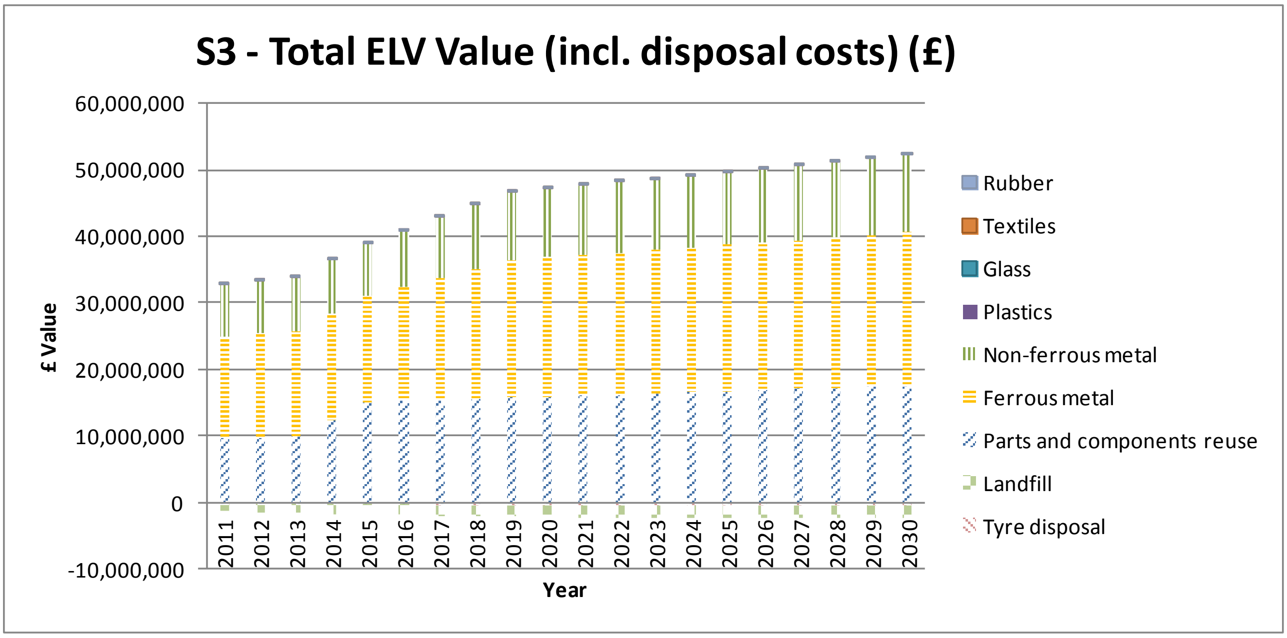

Figure 60 - Scenario 3 – 50% increase in value from parts and components reuse

The model projections show an overall economic value of ELV materials (net of disposal costs) of almost £32 million in 2011. In 2014 there is change from the business as usual scenario when more value is recovered from reused parts (average of £125 per ELV compared to previous average of £100 per ELV). In 2015 there is a further increase in revenue from parts reuse resulting from an increase in the average value per ELV of £150). These increases are partially offset by a reduction in revenues from metal available for recycling (ferrous and non ferrous). Costs are reduced through a reduction in material sent to landfill (plastic, glass and rubber). By 2030, the model projects an overall economic value of ELV materials (net of disposal costs) of just under £50 million. Considering this scenario from an individual ELV perspective, the economic value (net of disposal costs) changes from £327 in 2011 to £425 in 2030.

The environmental impact of this scenario is difficult to compare with the business as usual scenario as there is insufficient data identified to enable the calculation of the environmental impact of parts and component reuse.

The investment costs related to this scenario include the time taken by ATFs to develop a system of supply that is suitable for the target market and also the cost of developing a PAS standard to provide the market with a framework to measure quality of supply. Feedback from industry suggests that the annual certification costs of such a system would be around £2,000 to £5,000 per ATF. It is estimated that around £65,000 would be required to initially develop such a PAS which could be used by the industry and its customers.

There is also potential to support this scenario with policy guidance to help identify and remove (where possible) barriers to the reuse of vehicle parts and components by the public sector.

8.3.4 Comparison of scenario impacts

To isolate the projected impacts of each scenario it is necessary to consider the impacts relative to what may have occurred if the scenarios did not take place, i.e. relative to the business as usual scenario. Comparison is made in economic terms, environmental terms and combined social cost benefit terms. Note that for the environmental and social cost comparisons, only scenarios one and two are included as data was not identified to enable the environmental benefits of reuse to be calculated.

Economic comparison

Figure 61, below, shows a comparison of the projected economic impact (at a Scottish level) of the three scenarios discussed earlier in this section.

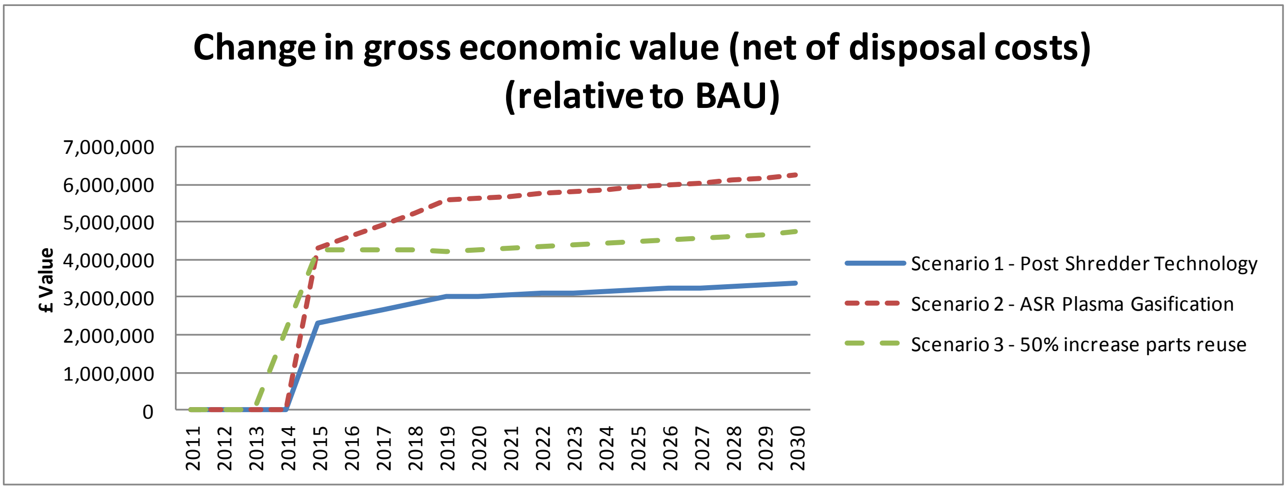

Figure 61 - Comparison of the change in gross economic value (net of disposal costs) relative to business as usual

The above comparison shows that scenario two (ASR plasma gasification) offers the largest increase in gross economic value at over £6 million per annum by 2030. This compares to over £3 million per annum by 2030 for scenario one (ASR Post Shredder Technology) and almost £5 million per annum by 2030 for scenario three (50% increase in parts reuse). These relative increases must, however, be viewed alongside the estimated investment costs for each scenario. Scenarios one & two are estimated to require capital expenditure investment of around £20 to £25 million for a PST plant and £20 million for a plasma gasification plant. Scenario three is estimated to require investment of £65,000 (relating to the development of a PAS) plus an additional £274,000 of upfront costs faced by ATFs setting up internal systems to comply with the PAS (based on each of the 137

ATFs incur costs of £2,000 each). Clearly, when considering changes in gross economic value relative to investment costs, scenario three is the best performing scenario.

Figure 62, below, compares the change in gross economic value at an individual ELV level.

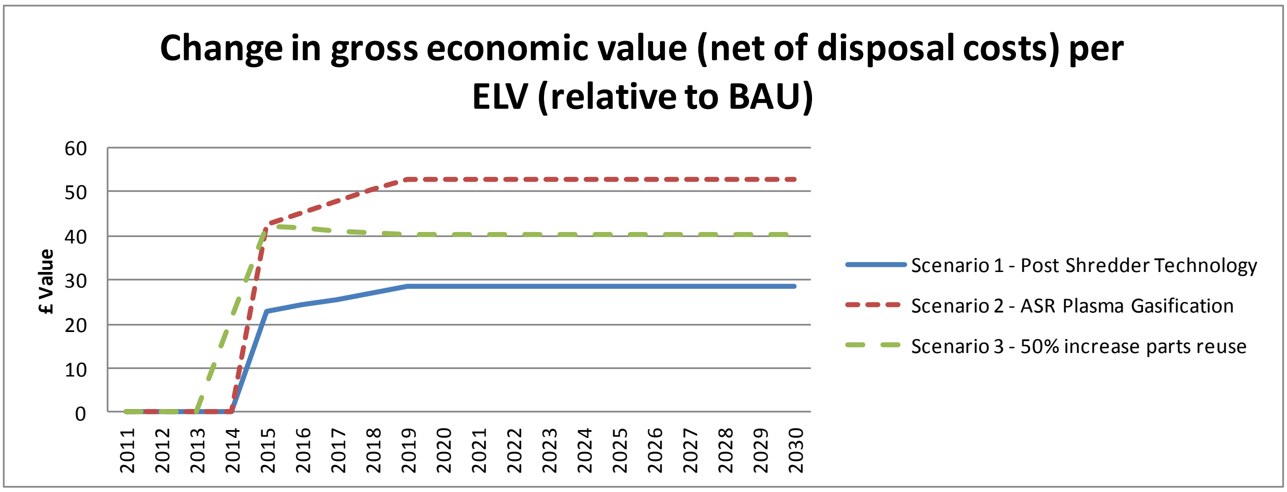

Figure 62 - Comparison of the change in gross economic value (net of disposal costs) per ELV relative to business as usual

The relative comparison obviously remains the same. Scenario three only generates an additional £40 per ELV, even though the average increase in revenue from reused parts and components is projected to be £50. This difference occurs due to some of the metal in the reuse components no longer being recycled. On balance the effect is positive as reused components will attract a higher value than could be achieved if sold for material scrap value.

Environmental comparison

Figure 63, overleaf, shows the comparative change in environmental benefits/costs, at a Scottish level, associated with scenarios one and two, relative to business as usual. Scenario 3 is not included due to the lack of data identified to enable calculation of the environmental benefits of reuse of ELV parts and components.

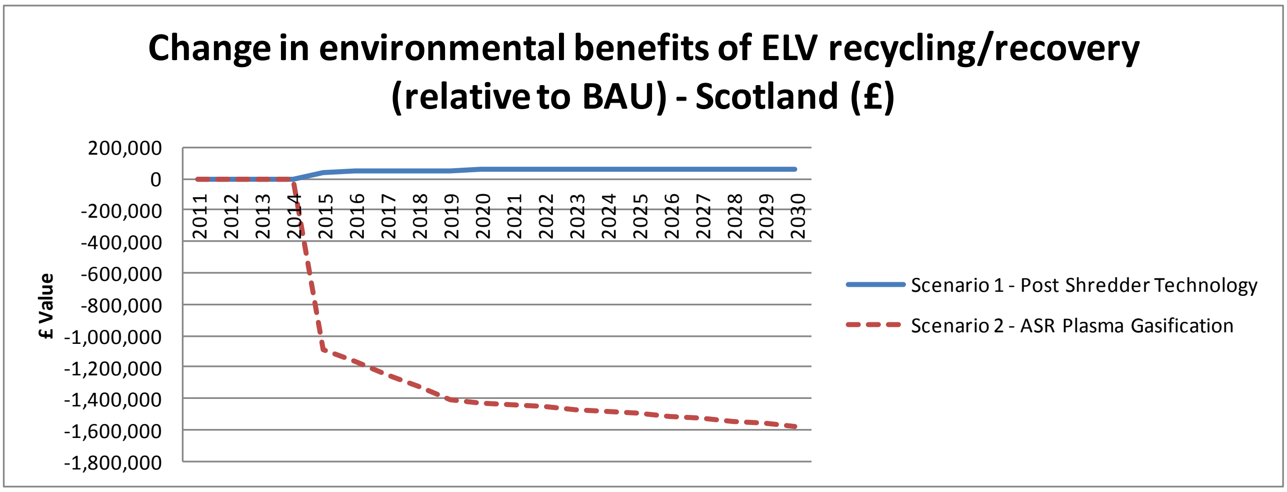

Figure 63 - Comparison of the change in environmental benefits of ELV recycling/recovery (relative to BAU) – Scottish level

The above comparison shows a modest benefit to the environment of scenario one and a significant environmental cost associated with scenario two. The former is due to the environmental benefits of recycling of plastic being almost cancelled out by the environmental costs associated with thermal treatment of residual material as part of the PST output. It should be noted that the environmental costs associated with thermal treatment used in this calculation are estimated from the greenhouse gas and other air emissions from treating plastic via an MSW incinerator (no alternative data for plasma gasification could be identified). Plasma gasification technology uses less air in the process than MSW incineration and, therefore, it is likely that the scale of environmental costs associated with treating plastic using this technology would be less than MSW incineration.

Figure 64, overleaf, shows the same environmental impact data but at the level of an individual ELV.

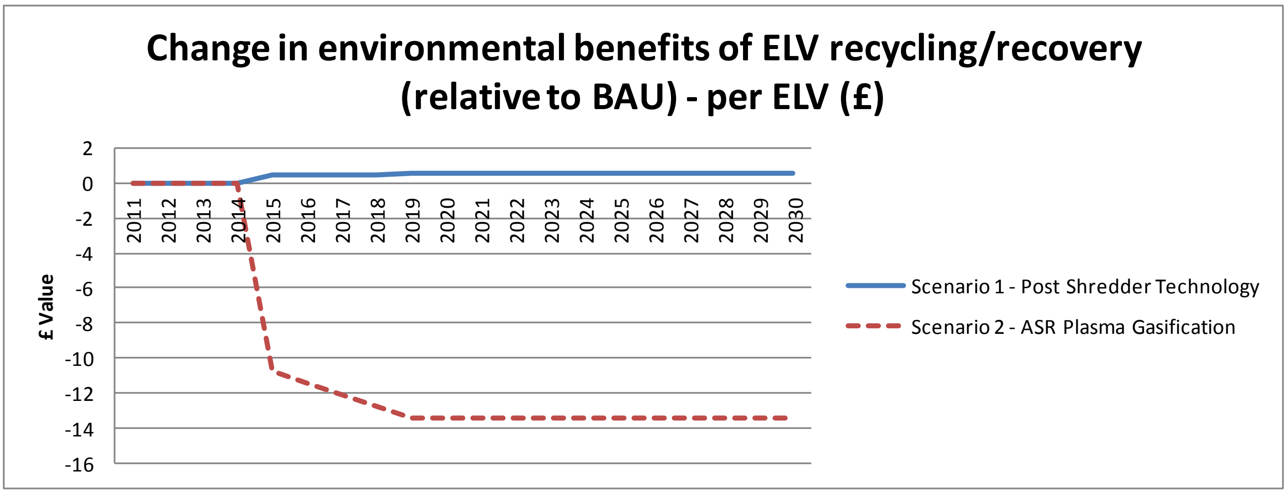

Figure 64 - Comparison of the change in environmental benefits of ELV recycling/recovery (relative to BAU) – per ELV level

Again the above figure shows how the environmental benefits of material recycling through a PST plant are almost cancelled out by the environmental costs of using a proportion of the output as a feedstock for energy from waste facilities.

Social comparison (combined economic and environmental)

Combining both the economic and environmental impact for scenario one and scenario two provides the projected social costs of each scenario. Figure 65, below, shows the comparison of social costs between the two scenarios, at a Scottish level.

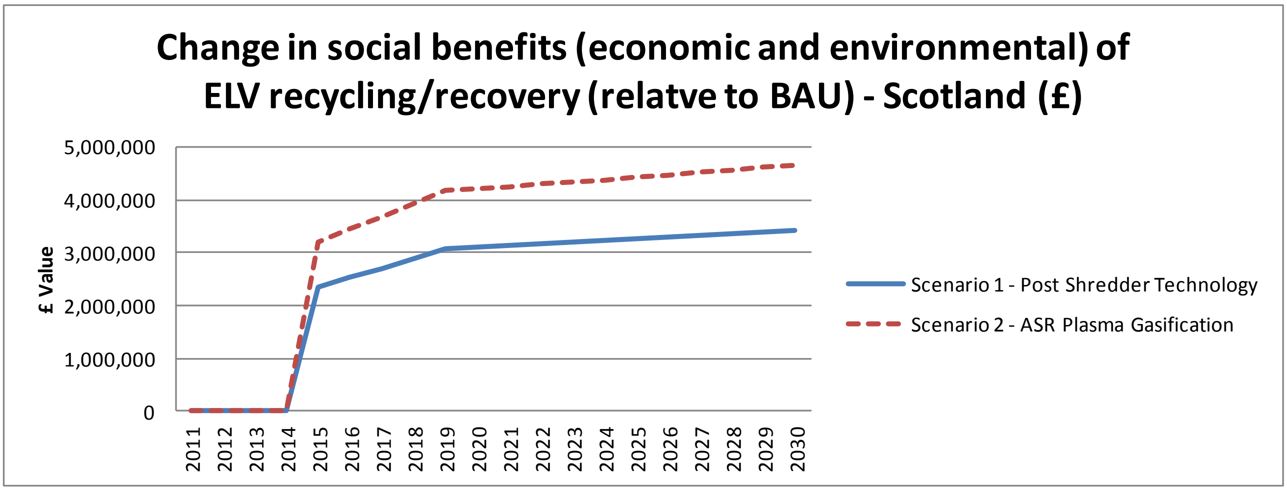

Figure 65 - Comparison of the change in social benefits of ELV recycling/ recovery (relative to business as usual) – Scottish level

The above comparison shows that, even accounting for the relatively significant environmental costs associated with scenario two, the option of ASR plasma gasification offers a greater overall social benefit to Scotland compared to scenario one (PST plant). Scenario three is not shown as the environmental benefits of parts and component reuse could not be calculated.

Figure 66, below, shows the same data at an individual ELV level.

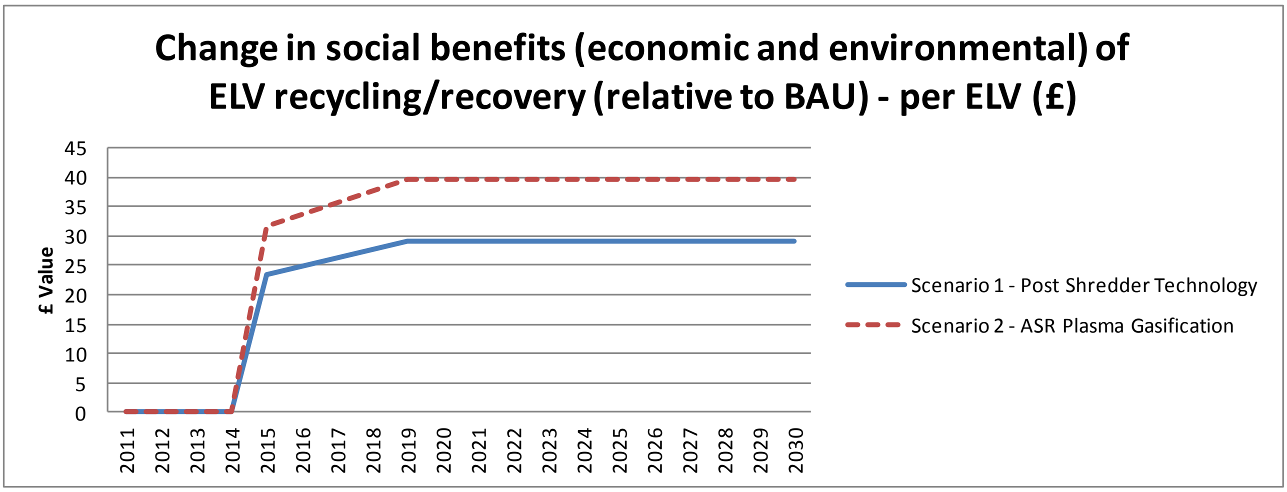

Figure 66 - Comparison of the change in social benefits of ELV recycling/ recovery (relative to business as usual) – ELV level

These projections suggest that scenario two offers an approximate £10 per ELV additional social benefit compared to scenario one.

The figure 67 shows the comparison of key estimated investment and return information based on the modelling.

Short term commercial opportunity	Minimum viable capacity	Estimated investment	Impact shown as relative to 'business as usual' case		
			Additional annual gross economic impact (net of disposal costs) by 2030	Change in the net annual environmental impact by 2030 - negative shown in ()	Combined change in annual social impact (economic + environmental) by 2030
Scenario 1 - Post Shredder Technology plant	60,000 to 100,000 T p.a.	£20 million to £25 million	£3.35 million	£0.06 million	£3.41 million
Scenario 2 - ASR plasma gasification plant	50,000 T p.a.	£20 million	£6.22 million	(£1.57 million)	£4.65 million
Scenario 3 - 50% increase in parts reuse	N/A	£65,000 for PAS and ~ £2,000 - £5,000 annual fees per ATF	£4.72 million	Not calculated due to lack of data	Not calculated due to lack of data

Figure 67 - Overview comparison of short term opportunities

The above figure suggests that the opportunity to increase value from higher levels of parts and components reuse offers a significant return on the initial investment in a Publicly Available Specification for automotive parts and components reuse. Of course, in addition to the initial financial investment in a PAS, there will be significant time and effort required to develop the reverse logistics networks to ensure service and repair garages have access to a sufficient range of quality parts and components at the correct time.

It should also be noted that investment in the Post Shredder Technology plant or ASR plasma gasification plant is based on continuing availability of ASR as a feedstock (although a plasma gasification plant would have more flexibility of input materials than a dedicated PST plant).

Considering these ASR treatment processes alongside the earlier medium to long term opportunities involving a shift to a circular economy suggests that, in the medium to long term, there would be a decreasing supply of shredder residue for these plants to process. The higher value achieved from greater levels of reuse, repair, refurbishment and remanufacture of parts and components would mean that less material would require recycling or downcycling. This presents a risk to investors in this type of plant but would not necessarily lock in the rest of the supply chain to use of these facilities due to the lack of long term contracts in place. Dismantlers are currently free to extract the parts, components and materials they choose from vehicles prior to shredding, and this is likely to remain the case. As demand for more core parts and components for remanufacture increases (for example) then the presence of PST plants and/or plasma gasification plants is unlikely to present a barrier to dismantlers responding to this demand.

9. Potential policy actions

This section describes a number of potential policy actions which could be considered in support of the short, medium and long term opportunities identified in the previous two sections.

Section 9.1 describes potential policy actions to disseminate knowledge about the opportunities identified (from this and potential future studies). These actions also include further engagement with the current and potential future supply chain.

Section 9.2 describes potential policy actions which could be taken to support the medium and long term opportunities. These actions focus on the broad objective of supporting the development of the circular economy.

Sections 9.3 to 9.7 describe a range of potential policy actions to address short term opportunities. These include:

- Awareness raising amongst ATFs regarding compliance with depollution processes
- Enabling measures to support reuse of vehicle parts and components
- Funding for study into shredder residue recycling plant
- Other measures to improve the level of recycling and quality of output material
- Investigate the reuse and recycling of high value metals and rare earth elements

When considering these potential policy actions it is useful to do so in the context of the waste hierarchy.

The Waste Hierarchy[108]

[108] Zero Waste Scotland

When discussing potential policy actions it is useful to consider how the action might impact on moving material up the waste hierarchy from disposal through to reduction.

Each of the above potential policy actions is now considered in turn.

9.1 Dissemination and further engagement with the supply chain

There is a need to disseminate information about the potential short, medium and long term opportunities to: companies operating in the ELV dismantling and shredding sector; government and regulatory representatives; vehicle producers and suppliers; companies currently involved in refurbishment and remanufacture of vehicle parts; potential new entrants into the remanufacture of mechatronic parts and; academics and researchers with relevant expertise.

This dissemination could be carried out via presentations at events, through specialist print and online publications, through specific supply chain workshops, etc. Dissemination through a workshop of supply chain representatives would also the opportunity to identify areas for future studies, research etc.

9.2 Stimulate and support moves towards a circular economy

In the short to medium term consideration should be given to the following potential policy actions:

9.2.1 Work with the Technology Strategy Board to identify short term pilot studies

Both sector and government representatives should work closely with the Technology Strategy Board (TSB) on any follow up funding support to the recently closed call for feasibility studies (Resource efficiency: New designs for a circular economy[109]). This would help identify the focus of future TSB funding in this area and whether any Scottish based companies had applied for funding during previous calls.

This potential action should be linked with the previously mentioned workshop of supply chain representatives to test whether any potential research projects might be pursued with funding support from the TSB.

9.2.2 Investigate the scope for a Centre of Remanufacturing Excellence

Work with existing expertise within Scottish (and other) universities, automotive manufacturers/remanufacturers and other companies, to scope a „Centre of Remanufacturing Excellence'. This could provide a focus to identify and overcome issues and develop opportunities in Scotland. Potential services could include company capability development support, training development, certification support, circular design

[109] http://www.innovateuk.org/content/competition/resource-efficiency-new-designs-for-a-circular-eco.ashx

support, industry led R&D (technical and business model), environmental assessments, policy support, etc.

9.2.3 Investigate options for other innovation and R&D hubs

Investigate the creation of innovation and R&D hubs to support the development of a circular economy – identifying technical and non-technical barriers and addressing via interdisciplinary teams.

9.2.4 Support standards development for remanufacturing

Promote clear standards for the activities which can be classed as remanufacturing (potentially based on BS 887-220:2010, which is in the process of being developed to an ISO standard). There is also potential scope to support this by piloting an accreditation system similar to the REVOLVE reuse standard[110] which could work as a „stepping stone' to companies achieving the BS standard and eventual ISO standard.

9.2.5 Investigate potential for public procurement to support the circular economy

Investigate the potential issues relating to the use of public procurement frameworks and contract specifications to drive the use of remanufactured content in new vehicles and the use of remanufactured parts and components in service and repair contracts.

A policy of setting minimum levels of reused, repaired, refurbished or remanufactured parts and components (as a percentage of total parts and components spend) could also be considered by the public sector as well as the private sector (where the latter is interested in improving its sustainability performance). This approach is already established in procuring items such as paper, construction materials, etc.

Whether a part or component is reused or remanufactured depends upon the extent to which it is safety critical. For example, a plastic wheel arch could be reused (as it is not safety critical) but items such as brake discs are more likely to be remanufactured.

9.2.6 Investigate education and skills needs for a circular economy

Develop a better understanding of the education and skills requirements of a future supply chain and identify emerging developments of education and skills training providers (including awareness raising within schools). This process should identify gaps and develop a roadmap to address these gaps.

9.2.7 Investigate options to support repurposing and upcycling

Identify current and emerging activities in Scotland and beyond about repurposing and upcycling (a specific area of downcycling is addressed in section 9.7). This is likely to involve sectors outside of the automotive sector, including the creative sector, renewable energy sector, etc.).

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[110] http://www.revolvereuse.com

Work with other sector support organisations to highlight the repurposing and upcycling opportunities arising from parts and components in the automotive sector.

9.2.8 Longer term potential policy actions to support a circular economy

In the longer term the following policy options should be considered:

- Tax credits for the purchase of remanufactured goods
- Regulatory requirements on companies to report material use in accounting
- Taxing material use rather than labour
- Policy and regulatory requirements to support the sharing of knowledge through the supply chain about design, disassembly, servicing, repair, refurbishment and remanufacture (to overcome commercial confidentiality barriers)

It is difficult to set a timeframe for the above longer term policy options (particularly where a fundamental change to taxation policy is involved). The short to medium term opportunities do, however, present a real opportunity to advance the situation in Scotland to take advantage of emerging new business opportunities which have the potential to contribute to economic growth, job creation and a reduction of the environmental burden.

9.3 Awareness raising regarding compliance with depollution processes

Based on feedback received from ATFs during the research survey a significant number of respondents indicated they did not have (or plan to invest in) specialist equipment to recover and store air conditioning gases. A potential policy option is to raise awareness of the legal responsibilities of ATFs to carry out this depollution task. This awareness raising could be targeted at ATFs and SEPA officers responsible for monitoring licensed ELV treatment sites.

9.4 Enabling measures to support reuse of vehicle parts and components

9.4.1 Supporting the development of a Publicly Available Specification for reuse

As described in section eight, an increase in the reuse of parts and components is projected to have a significant positive economic impact in Scotland. There are several, well understood, barriers to achieving this commercial opportunity. The development of a Publicly Available Specification for reused ELV parts and components has been identified as having the potential to reduce barriers related to market confidence in the quality of the product. There is, therefore, an option to support the development of a PAS at an estimated one-off cost of £65,000. This PAS would be relevant to the UK market.

9.4.2 Developing the market for parts and component reuse in the private sector

There are already examples of ATFs working on pilot projects with the insurance industry to increase the use of reused parts and components within service and repair garages.

This should be continued and monitored to identify good practice and examples of successful relationships and systems being established.

9.5 Funding for study into shredder residue recycling plant

One of the key issues identified in this project is that currently available PST plants to recycle material from ASR require a level of investment (£20m to £25m) that needs a minimum of around 60,000 to 100,000 tonnes per annum throughput of shredder residue. The arisings of shredder residue in Scotland (from ELV and WEEE) are estimated to be around 60,000 tonnes and, therefore, a recycling facility, based on the technology identified during this research project, is at the edge of commercial viability and susceptible to the threat of contract negotiations by shredder residue suppliers once any such plant were operational (given the need to process all Scottish arisings).

Three ASR processing plants are currently operating in England (where there are greater levels of ASR arisings) but feedback from shredders in Scotland suggest that the transport costs to the nearest facility (plus the gate fee) make this option uneconomic compared to the cost of landfill. As landfill tax increases, an alternative option being investigated by shredders is for the material to be treated by waste management companies (who mix it with other waste streams) for use in the production of SRF. Due to the significant EfW capacity in other parts of Europe it has been suggested that this route will be more economically attractive to shredders than transporting to ASR processing plants in England. The scenario suggested by some Scottish based shredders is that as landfill tax increases, the gate fee charged by waste management companies (which produce SRF) will fall below the cost of landfill. This gate fee will also be less than the total cost (gate fee plus transport cost) of sending ASR to England for some level of recycling.

An option to address this issue with transport costs would be to provide support to fund research and development of a smaller scale processing facility that could be based in Scotland or enhancements to existing shredder processes which could commercially recover more non-metallic materials.

9.6 Other measures to improve the level and quality of recycling

There are a number of other measures that could be considered to improve the level of recycling and the quality of the output material produced. These include:

9.6.1 Instigate changes to the DVLA process to only deregister based on a COD

Based on feedback from the dismantling sector, the non-issuing of CODs is their main concern. As previously mentioned, in section 3.5.1, the last owner of an ELV can complete and submit form V5C to the DVLA. The DVLA does not appear to carry out a systematic cross check that a COD has been issued when the V5C form is received. The

V5C form does explain the need to take the ELV to an ATF and that a COD *should* be issued but this does not always happen.

In the Netherlands, the deregistration system is such that the last owner receives a COD that is the same document they require as evidence that they are no longer liable to pay insurance, tax and ensure the vehicle has a current MOT. The last owner has, therefore, a higher level of incentive to obtain this document, which can only be issued by an ATF.

The result of the lack of systematic cross-checking of the V5C form with the COD database is that a significant proportion of ELVs are treated by unauthorised operators who do not face the same compliance costs as ATFs. This allows these unauthorised operators to offer more competitive prices for ELVs to last owners who do not appear to be penalised for not obtaining a COD. In turn, this leads to monies being lost to the registered sector, which impacts on the availability of investment capital. If the deregistration system were to require confirmation that a COD had been issued (and potentially penalties for the last owner if it is not) then this would make it harder for unauthorised operators to obtain scrap vehicles.

To resolve this issue the DVLA would have to remove the ability for vehicles to be deregistered by any means other than a through a COD being issued, except in exceptional circumstances.

9.6.2 Introduction of an ELV funded system to incentivise last owners

In some other countries (e.g. Denmark and Norway), the last owner is offered a financial incentive to take their ELV to an ATF and obtain a COD. This is possible due to funds being created though payments via annual insurance premiums (Denmark) or additional fees on the original purchase price of the vehicle (Norway).

The introduction of such a funded scheme would act to increase the incentive to obtain a COD from an ATF and, therefore, reduce the monies lost to the unauthorised sector. The impact of this would be the same as detailed in section 9.6.1 (i.e. unauthorised operators would find it harder to obtain scrap vehicles).

This would require renegotiation of the producer responsibility aspects of the ELV regulations currently in place in the UK. Such a move would be rendered partially redundant if the incentive for last owners could be created by changes to the deregistration system, as described in 9.6.1.

9.6.3 Introduction of an ELV funded system to incentivise ATFs

Another example of a type of funded system, which could be considered, is one that rewards the ATFs for achieving certain levels of dismantling. Such systems are present in the Netherlands and Poland, for example.

In both cases, the funding for this system is raised through monies paid at the initial purchase of the new vehicle. The funds are controlled centrally by a single organisation.

In the Netherlands, the fund makes payments to ATFs based on the achievement of the removal of specific parts and components (e.g. plastic bumpers and dashboards). This clearly has the potential to directly impact on the quality of materials removed for recycling as it encourage this to be carried out before shredding.

9.6.4 Regulation to mandate removal of specified materials at dismantling stage

An alternative to providing a financial incentive to ATFs to remove specified materials at the dismantling stage is to create regulations that require this to be carried out. This could be considered to have a direct impact on improving the quality of recycled material by removing it from the waste stream prior to shredding.

There is, however, a potential risk from introducing such a policy. If ATFs were required to remove parts and components, such as plastic bumpers, glass etc., then this would add costs to their business operation (it is not economically beneficial to remove these items or the dismantlers would already be doing so – the increased labour cost does not compensate for the value achieved from the recovered material, and the lost revenue from a reduction in weight sold to shredders). These increased costs would reduce the amount they could offer to last owners for their ELVs relative to the price offered by an unauthorised operator (given that the latter is not adhering to existing regulations, it is unlikely they would do so with additional regulations). In the absence of a cross-check on the issuing of CODs, as a precondition of deregistration, this policy option is likely to result in consequences, as described above.

Some countries (e.g. Austria and Sweden) have such a legal obligation in place for (at least part of the) glass screens to be removed prior to shredding.

9.6.5 Pilot project to assess the impact of shredder pricing differentials

In addition to consideration of regulation to drive the removal of specific parts and components (e.g. glass/plastic bumpers, etc.) there may also be an opportunity to investigate whether commercial drivers can change market behaviour of dismantlers. Consideration could be given to working with a shredder operator to assess the impact on pre shredder removal of glass and plastics of differential prices being offered for ELV hulks. This project would also assess the commercial impacts on all parties.

9.6.6 Introduction of an ASR landfill ban or higher landfill tax band

Another policy option that could be considered is the introduction of a landfill ban on ASR or an increase in the rate applied to ASR. The aim of this would clearly be to incentivise treatment options further up the waste hierarchy.

If this option were to be applied to ASR arising in Scotland alone then there is a risk that the increasing cost placed on shredders may make the price they are able to offer dismantlers for the vehicle hulks uncompetitive compared with shredders in England. This may lead to vehicle hulks being treated in England, especially in areas around the border where transport costs would be at their lowest.

To enable time to secure investment capital and build treatment facilities, any landfill ban or increased tax rate would have to be set at a reasonable point in future years so that shredders had an alternative option to landfill.

9.6.7 Develop the market for non metallic material use through public procurement

As discussed earlier, there is no economic incentive for dismantlers to remove large plastic components prior to shredding (except in the case where they are removed with the intention of reuse). The quality of plastic removed from ELVs at the dismantler stage will be much higher than that recovered from ASR (which will be contaminated and a mix of polymer types). There is an opportunity to investigate whether public procurement can be used to drive the market for products containing plastics recovered from ELVs.

The same argument can be made for using public procurement to drive demand for material recovered from tyres through use in applications such as publicly funded road and cycle path construction.

9.7 Recovery and reuse of high value metals and rare earth elements

The commercial viability of recovering rare earth elements from ELVs is at an early stage, as discussed in section 4.2.4. The levels of rare earth elements in ELVs are relatively low and dispersed throughout different components. This makes their recovery expensive. An alternative policy to be considered would be to develop pilot projects between dismantlers and/or shredders and vehicle producers to identify parts and components containing rare earth element (e.g. permanent magnets) and investigate the feasibility of removing them at dismantling or post shredder stage, either for reuse (in the case of dismantlers) or recycling (which would include magnets recovered post shredder). The investigation could also cover the potential reuse/remanufacture of other high value metal containing parts, such as catalytic convertors.

9.8 Summary of potential policy actions

The above discussion on policy options can be summarised as follows.

Potential Policy Actions
1 Dissemination and further engagement with the supply chain to identify opportunities, stimulate supply chain networking and collaboration and support further feasibility studies and pilots
2 Stimulate and support moves towards a circular economy
2.1 Work with the Technology Strategy Board to identify short term pilot studies in the area of 'new designs for a circular economy'. This could provide funding support for feasibility studies by different parts of the Scottish supply chain
2.2 Investigate the scope for a Centre of Remanufacturing Excellence to provide a focus for academics, researchers, enterprises and regulators with an interest in remanufacturing in the automotive sector
2.3 Investigate options for other innovation and R&D hubs to address challenges and opportunities in areas beyond remanufacturing, such as reuse, repair and refurbishment
2.4 Support standards development for remanufacturing to help reduce market barriers and increase demand
2.5 Investigate the use of public procurement to support the circular economy by stimulating demand for remanufactured refurbished, repaired and reused vehicles, parts and components
2.6 Investigate education and skills needs for a circular economy to ensure relevant skills and capabilities are available to existing and new parts of the supply chain
2.7 Investigate options to support repurposing and upcycling for parts and components no longer suitable for reuse, repair, refurbishment or remanufacture to help maximise value created in Scotland
2.8 Consider longer term potential policy actions to support a circular economy to ensure future regulatory and fiscal policy development aligns with the framework required to support a circular economy
3 Awareness raising amongst Authorised Treatment Facilities regarding compliance with the End of Life Vehicle depollution process to ensure the correct equipment and skills are available
4 **Enabling measures to support reuse of vehicle parts and components to remove barriers to specification and procurement**
4.1 Supporting the development of a Publicly Available Specification for reuse to reduce market barriers and increase demand
4.2 Develop the market for parts and components reuse in the private sector by supporting pilots to establish best practice
5 Provide funding for a study into shredder residue recycling plant to investigate commercially viable technical solutions for individual shredders or a merchant facility (at a scale that matches individual shredder/Scottish arisings of shredder residue)
6 Other measures to improve the level and quality of recycling to minimise material lost to landfill and maximise economic return
6.1 Instigate changes to the DVLA process to only deregister based on a COD to reduce the availability of End of Life Vehicles to unauthorised operators
6.2 Introduction of an End of Life Vehicle funded system to incentivise last owners to deal with Authorised Treatment Facilities
6.3 Introduction of an End of Life Vehicle funded system to incentivise Authorised Treatment Facilities to achieve specified levels of material separation prior to shredding
6.4 Introduction of regulation to mandate removal of specified materials at the dismantling stage to ensure higher quality of plastic and glass are recovered
6.5 Support a pilot project to assess the impact of shredder pricing differentials to incentivise dismantlers to remove specified non metallic materials prior to shredding
6.6. Introduction of an landfill ban on Automotive Shredder Residue or inclusion of it in a higher landfill tax band to support the development of alternative treatment technologies
6.7 Support the development of markets for non metallic materials recovered at the dismantling stage through public procurement to incentivise dismantlers to remove items such as plastics and glass prior to shredding
7 Support studies into the recovery and reuse of high value metals and rare earth elements to obtain more value from materials and reused/remanufactured high value parts and components

Figure 68 - Summary of potential policy actions

The potential policy actions in the above figure are based on the views of various stakeholders, (including from both industry and government) and taken together with evidence found from other countries. It provides a comprehensive list of options to address the key challenges and opportunities arising from short, medium and long term trends in the automotive sector. These opportunities have the potential to deliver significant economic social and environmental benefits for Scotland.

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