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AGREEMENT

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Dismantling methods and protocols in a Circular Economy Framework - Composite recovery in the automotive industry

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European foreword

This CEN Workshop Agreement (CWA 17807:2021) has been developed in accordance with the CEN-CENELEC Guide 29 “CEN/CENELEC Workshop Agreements – A rapid prototyping to standardization” and with the relevant provisions of CEN/CENELEC Internal Regulations – Part 2. It was approved by a Workshop of representatives of interested parties on 2021-01-12, the constitution of which was supported by CEN following the public call for participation made on 2020-11-24. However, this CEN Workshop Agreement does not necessarily include all relevant stakeholders.

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Introduction

During the last decades, waste generation has become a serious problem for our highly industrialised societies. "Ensuring the sustainable management of natural resources and wastes" is one of the four priority areas (climate change, biodiversity, health, and resource use and waste), which includes the development of a 'Thematic Strategy on Waste Recycling' and initiatives in the field of waste prevention, notably proposals on European Community waste prevention targets.

These protocols propose a strategy on waste management, which includes a hierarchy of options in which primary emphasis is laid on waste prevention, followed by promotion of preparing for re-use, recycling and other material recovery.

This goal requires a complete value chain revision. The following steps must be reviewed: design, production, distribution and collection, business models, users, and stakeholder's platform, and, finally, management of waste streams.

At the end of life of circular designed products, new more homogeneous waste streams will allow for more uniform recovered materials to be fed back into the production line. After having studied the circular economy model, waste sorting and characterization technologies as well as material conditioning technologies, as well as minimization, substitution and phase out of chemicals that hamper recycling, its integration as raw materials in production lines, it is time to standardize waste streams managements to close the loop of this circular economy model.

Advanced solutions for collection, sorting and pre-treatments innovations have allowed an increase of more than 5 % the recyclable materials that could be used in current ELVs bulky wastes.

These protocols aim to guarantee an appropriate identification and characterization of incoming wastes and selection of recovered materials after sorting treatment and strengthen this link within chain value working on at least on 95 % of raw materials.

1 Scope

This document overviews, optimizes and validates the strategies and technologies for collection and material recovery (plastics, foam, glass, fibres from vehicle parts) for (re-) manufacturing, in addition to parts that are already being recycled.

Current recycling systems for ELV's are designed to valorize the metallic content. But nowadays, there is an ongoing surge to use non-metallic parts, low value, and complex materials in the vehicle (and future ELV) to reduce their carbon footprint.

2 Normative references

The following documents are referred to in the text in such a way that some or all their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN ISO 1043, *(serie),* Plastics — Symbols and abbreviated terms

DIN 6120:2019, *Marking of packaging and packaging materials — Plastics packaging and packaging materials*

VDA 260:2007, *Components of motor vehicles — Marking of material*

SAE J1344:2017, *Marking of Plastic Parts*

3 Terms, definitions, and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1.1
circular economy
economy that is restorative and regenerative by design, and which aims to keep products, components and materials at their highest utility and value at the times, distinguishing between technical and biological cycles

Note 1 to entry: A circular economy follows the European waste hierarchy and builds upon four principles: 1. Sobriety, 2. Durability at the heart of all the products, processes, and services, 3. High value retention and high 'loopability' of materials, 4. Out designing of substances of concern and hazardous substances.

3.1.2
reuse
process by which a product or its parts, which are not waste, are used again for the same purpose for which they were conceived

[SOURCE: Adapted from EU Waste Framework Directive 2008/98/EC article 3.13]

3.1.3
repair
process of returning a faulty product to a condition where it can fulfil its intended use

3.1.4
recycling
recovery operation of any kind, by which waste materials are reprocessed into products, materials, or substances whether for the original or other purposes excluding energy recovery and excluding the reprocessing into materials that are to be used as fuels or for backfilling operations

[SOURCE: Adapted from EU Waste Framework Directive 2008/98/EC article 3.17]

3.1.5
refurbishing
renovate and redecorate

3.1.6
downcycling
recycling of waste where the recycled material is of lower quality and functionality than the original material

3.1.7
upcycling
reuse (discarded objects or material) in such a way as to create a product of higher quality or value than the original

3.2 Abbreviations

For the purposes of this document, the following abbreviations apply.

ELV	End of Life Vehicles
ABS	Acrylonitrile Butadiene Styrene
PC	PolyCarbonate
PVD	Physical Vapor Deposition
PPE	PolyPhenylene Ether
PA	PolyAmide
PP	PolyPropylene
GDP	Gross Domestic Product
ICT	Information and Communication Technology

4 Description

Throughout its evolution and diversification, our industrial economy has hardly moved beyond one fundamental characteristic established in the early days of industrialisation: a linear model of resource consumption that follows a 'take-make-dispose' pattern.

Companies harvest and extract materials, use them to manufacture a product, and sell the product to a consumer—who then discards it when it no longer serves its purpose.

A circular economy is an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models. It relies on the waste hierarchy that gives the following priority order in waste prevention and management: prevention, preparing for reuse, recycling, other recovery, and disposal.

This study is focused on looking for opportunities to change waste streams into new raw materials. See Figure 1.

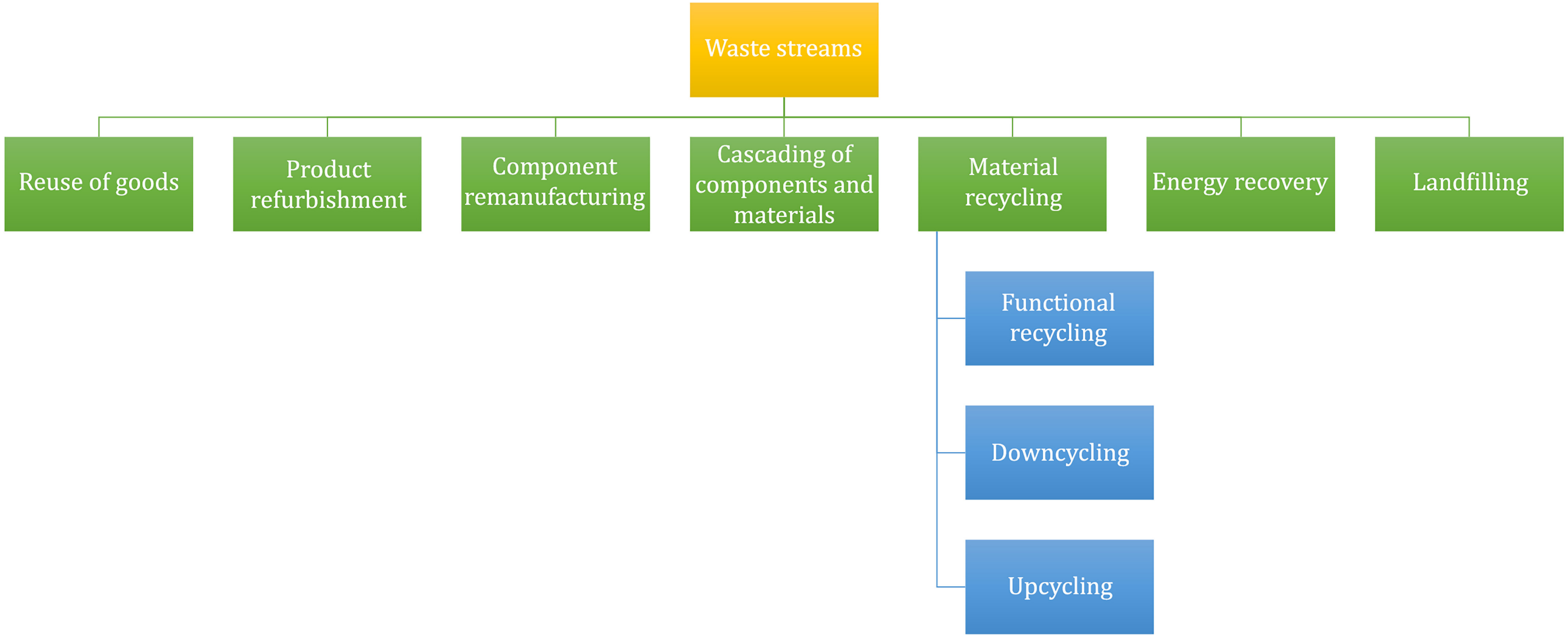

Figure 1 — Waste streams management options[1)]

[1)] *Reference to circular economy.*

5 Dismantling tasks in automotive industry

5.1 General

Post-consumer plastics waste or materials occurs as soon as the product or the engineering system (appliance, vehicle, etc.) of which it forms a part has reached the end of its life cycle and must be disposed of. The injection moulded part and hence the material of which it is made is then aged (weathered and mechanically or thermally stressed), soiled, contaminated with operating fluids, as a function of the purpose it has served, and may have been permanently modified by the user, so that it is no longer identical with the starting component or material.

Post-consumer plastic waste is generally disposed of in an indiscriminate fashion today, as part of the used product. The recycling of used materials, which constitutes the target generally involves the parts being dismantled, identified, and sorted, compacted for transport, prepared, homogenised, compounded and marketed prior to re-use. The material cycle depicted also a highly complex quality cycle. It can be readily seen that each customer up to the final consumer is simultaneously a supplier and hence is not also someone who generates quality. Now that it has been seen that the material recycling of post-consumer waste is technically feasible in a large number of cases, economic observations are being included in the recycling studies carried out.

Based on these economic observations, it is possible to estimate the cost of a series of the individual operations. Yet, however, it is too early to draw up balance sheets.

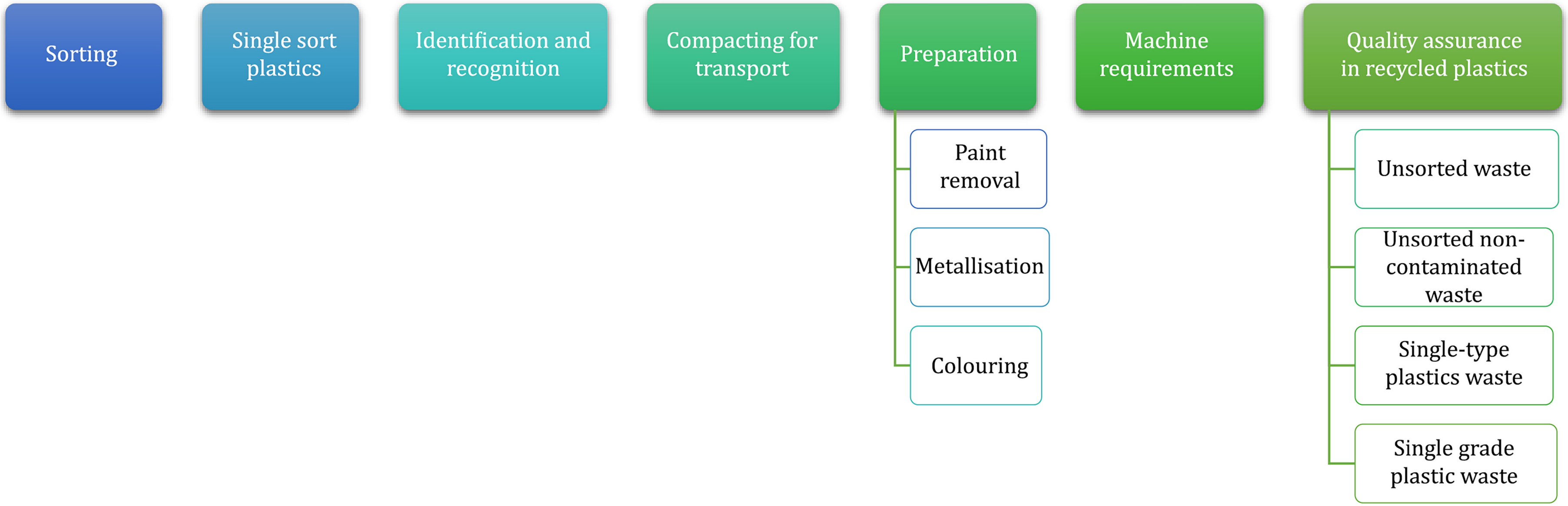

Figure 2 — Automotive sector present situation summary

5.2 Single-sort plastics

Used material correctly sorted into individual types will be the first requirement that raw material manufacturers impose to those who are obliged to take back plastics in future or on the third parties that they commission to do this work. Only if this requirement is fulfilled can mechanically recycling of the used material be attempted with any hope of success. This doubtless constitutes a particularly fundamental requirement and one that will scarcely be possible to fulfil in many cases.

The individual used material fractions must be clearly characterized if they are to be fed into the recycling processes that are available so far. Under certain conditions, this type of characterization may also specify the admissibility of contamination with other polymers (foreign polymers), providing that the stipulated levels are not exceeded.

5.3 Identification and recognition

The most important prerequisite for obtaining single-sort fractions is the reliable recognition of the plastic involved or of its principal component, which needs to be defined. This calls for two criteria, firstly, a recognition method and, secondly, a recognition characteristic or identification mark. Dismantling by hand based on dismantling manuals is not sufficient and can only be accepted for a transitional period.

5.4 Compacting for transport

If the identification of the plastic and hence the quality of the dismantled post-consumer waste has been ensured, it is the necessary to shred the material and to compact it for the journey from the dismantling plant to the recycler (transport compaction) to reduce the transport costs. Sorting errors can scarcely be rectified at this stage or can only be rectified at great expense. The shredded material that is to be transported thus constitutes a quality-assured product for future recycling material loops.

5.5 Preparation

The preparation of production or post-consumer waste serves to ensure that the thermoplastic is recovered with an optimum level of purity and in the geometry that is required for the plasticising operations. The resultant product is designated “defined regrind”. Typical preparation operations include grinding and air separation, washing and drying, ply separation, metal elimination, density separation and decontamination. Knowing which of the above operations, or additional methods should be used, either in isolation or in combination with others, will depend on the nature of the recycling problem on hand.

5.6 Paint removal

Many plastic moulded parts are painted for aesthetic reasons and/or to provide protection against weathering. In many cases, the paint is not compatible with the coated plastic. Depending on the nature of the plastic, therefore, it is possible for the paint to have a notch effect when it is worked into the material and thus lower the notched impact strength of the plastic, or even damage it. A mechanical process has been developed for the removal of paint from moulded parts. This permits quantitative separation and removal of the paint and thus ensures optimum conditions for the mechanical recycling of the plastic that has initially protected by the paint.

5.7 Metallization

As with painting, the metal coating of plastics serves both to enhance the appearance of plastics moulding and to provide protection against weathering. The chief variant is galvanochemical coating using ABS or ABS+PC which gives the plastic a metal look (Chromium-plating). In addition, plastics can be coated with aluminium by means of sputtering or the PVD process. Depending on the geometry of the moulded part and the resultant surface/volume ratio, it is possible to achieve metal components of up to 20 % through electroplating. A cold grinding process has been developed for the removal of the metal component. This exploits the dissimilar coefficient of thermal expansion of the two components. Employing this process, it is possible to reduce the metal component in pure regrind to ≤ 0,5 %. The subsequent “dilution” with virgin material in a ratio of 80/20 then gives a recycled plastic with a metal component of approximately 0,1 %.

5.8 Colouring

The colouring of recycled materials represents an extraordinarily difficult problem. It goes without saying that such a heterogeneous mixture of parts and materials can only give black pigmented regrind even after successful reprocessing in respect of mechanical, thermal, and processing properties.

5.9 Machinery requirements

The injection moulded will not normally encounter any problems when reprocessing plastics (regrinds). A plastic that has undergone preparation in the form of compounding will be available in the form of granulates. It must, however, be borne in mind that regrind has been subject to two additional processing steps involving thermal stressing (initial processing and compounding). The degradation that inevitably occurs is generally reflected in changed flow behaviour. The breakdown of the molecular chain (lower molecular mass and broader molecular mass distribution) leads to an increase in the flowability by comparison to the original material, which, in turn, affects the process parameters. The cavity can thus be filled more rapidly, thereby improving the pressure propagation inside the cavity during the compression and holding pressure phase. This makes the parts heavier and bigger. When regrind or mixtures of regrind and virgin material are processed, it is thus not possible to assume a constant product. Considerably wider tolerances will have to be accepted, at the very least. Machines with good process monitoring facilities or process control systems should thus be employed to produce quality mouldings.

Over and above this, there is a series of other requirements that need to be placed on the machine to permit the following objectives to be met: gentle melting, low residence time, good homogenisation, acceptance of mixed plastic feedstocks, acceptance of a non-uniform granulate feedstock or mixed granulate feedstock, and acceptance of feedstock with additives.

5.10 Quality assurance in recycled plastics

Quality of moulded parts implies the suitability of a part for its intended purpose, i.e., its serviceability. However, in many plastics applications, aesthetic, optical quality and processability also play a role. This, however, is not enough to secure the quality of the moulded parts. Even if high-quality raw material is used, a design or a form of processing that is nor suitably tailored to plastics can lead to moulded parts which fail to meet up the specifications in terms of their aesthetic, optical and technical quality.

Waste must be cleaned and have foreign materials removed from it. If possible, it should be separated into individual types or grades. The waste must then be ground. The grind, together with any additives that may be incorporated for post-stabilisation is processed into a moulding feedstock by means of compounding once again.

Different quality assurance and quality inspection measures will be required for the stages involved in the creation of the moulding compound, as a function of the point of departure (raw material or waste). The main difficulty encountered in the production of recycled lies in the starting product “waste”. It is possible to draw a distinction between four different types of waste, as a function of its origin.

5.11 Unsorted waste, such as waste from shredder plants

The unsorted waste, such as waste from shredder plants is generally contaminated with foreign materials that either cannot be removed or can only be removed at great expense. The different types of plastic contained in the waste will not generally be compatible. The logistics problems are least serious with this type of waste.

5.12 Unsorted, non-contaminated waste

Unsorted waste, if it is a non-contaminated waste, it can generally be cleaned more easily. The compatibility of the different sorts of plastics must be checked in each individual case. Present-day assemblies are frequently already made of types of plastic that are compatible with each other when reprocessed. Logistic problems are caused by the fact that the articles must be taken to collection points or to the producer's and then dismantled there.

5.13 Single-type plastics waste

A single-type plastic waste contains the same formula in is composition, i.e., un single-type is Polypropylene 30 % glass short fibre reinforced. This does not generally cause any difficulties in respect of compatibility. Care must, however, be taken to ensure that no "toxic waste", such as additives that have been banned in the meantime, are brought with the waste.

5.14 Single-grade plastic waste

A single-grade plastic waste contains a common base of plastic type, but contains different grades of additives, i.e., un single-grade is Polypropylene 30 % glass fibre reinforced and Polypropylene 15 % glass fibre reinforced. This generally offers the most favourable prospects for reprocessing. There are not usually any problems with cleanliness or compatibility. A higher logistics outlay is necessary. However, since products that have been manufactured at only on production plant, or in just a few locations, can occur as post-consumer waste anywhere in the world and need to be collected again.

In line with the four types of plastic waste, it is also possible to divide the recycled bulk made from these different types into four quality grades. See Table 1.

Table 1 — Quality of recyclates moulding compound

Recyclates Quality grades	Type of plastic waste	Serviceability	Aesthetic/Optical quality	Processability
A	Single-grade	Like virgin material, reduced dynamic stress ability	Like virgin material, if coloured otherwise rather poor	Like virgin material, Frequently with greater flowability
B	Single type (sorted)	For reduced requirements	Good surface colour: only dark shades	Reduced processing range, greater
C	Unsorted non-contaminated	For very low – level requirements	Very poor	Very poor, compression moulding
D	Unsorted contaminated	Not generally suitable for any application	Very poor	Very poor, compression moulding

This outcomes from the following **data study**, looking to accomplish these performance indicators:

i. Avoid harm.

ii. Reuse or recycle 95 % of material.

iii. Valuable material.

Figure 3 — Sample of studied parts – Courtesy of MICROCAB and MAIER

Table 2 — Most valuable item

Dismantling task	Main content	% total weight of the vehicle
Electrical wiring	PVC and copper	0,96 %

Table 3 — Hazardous items

Dismantling task	Main content	% total weight of the vehicle
Hazardous waste: Battery, diesel oil, oils, water, filters, and gear oil	Lead battery, fluids, and filters	1,44 %

Table 4 — Summary of plastics found & metals not recovered automatically

Dismantling task	Main content	% total weight of the vehicle
Front and rear bumpers, mudguard	PPE	4,04 %
Radiator fan, nozzles, and tanks	PA	1,15 %
Seats	ABS	0,10 %
Instrument panel - dashboard	PP	0,29 %
Door panel	PP	0,48 %
Roof	PP/ABS	0,57 %
Engine and mechanic	Iron	27,88 %

Table 5 — Summary of metals in very small quantities

Dismantling task	Main content	% total weight of the vehicle
	Other metals	14,62 %

Table 6 — Summary of items recycled automatically or mandatory

Dismantling task	Main content	% total weight of the vehicle
Wheels and tires extraction	Tires	5,77 %
Body	Steel	30,77 %
Windows	Glass	2,88 %
Rubber and fabrics		3,35 %

ELV parts have been analysed by dismantling process; defining three cases: mandatory, automatized, or manual extraction with enough pureness to be sold and cross info with percentages.

Table 7 — Mandatory parts to be removed

Dismantling task	Main content	% total weight of the vehicle
Hazardous waste: Battery, diesel oil, oils, water, filters, and gear oil	Lead battery, fluids and filters	1,44 %
	Oil, gear oil, water, fuel	2,21 %
	Filters	0,96 %
Wheels and tires extraction	Tires	5,77 %
	Rubbers	3,08 %

Mandatory wastes are processed due to potential pollution of soil, water, and air, and to awareness of misuse of some hazardous contents.

Table 8 — Automated removing of parts

Dismantling task	Main content	% total weight of the vehicle
Electrical wiring	PVC and copper	0,96%
	Other metals	14,62%
Body	Steel	30,77%

Automatized extraction of metals and alloys such as iron, steel, aluminium, and copper are the core business of present ELV vehicle-companies.

Table 9 — Remaining parts

Dismantling task	Main content	% total weight of the vehicle
Front and rear bumpers, mudguard	PPE	4,04 %
Radiator fan, nozzles, and tanks	PA	1,15 %
Seats	ABS	0,10 %
Instrument panel- dashboard	PP	0,29 %
Door panel	PP	0,48 %
Roof	PP/ABS	0,57 %
Electrical wiring	PVC and copper	0,96 %
Windows	Glass	2,88 %
Rubber and fabrics		3,35 %
Engine and mechanic	**Iron**	**27,88 %**
Partial amount		**40,74 %**

NOTE The light fraction is formed by plastics and other materials. In this case, the light fraction is 12,86 %. This percentage is the result of this operation: [40,74 % (Partial amount) - 27,88 % (Engine & mechanic)].

Table 10 — Most valuable parts at present

Dismantling task	Main content	% total weight of the vehicle
Electrical wiring	PVC and copper	0,96 %
Engine and mechanic	Iron	27,88 %
	Other metals	14,62 %
Body	Steel	30,77 %
Partial amount		**74,23 %**

There is an important percentage of “LIGHT FRACTION” that, at present, has no way to be competitively recycled, neither technically, nor economically. Throughout the methods contained in this draft these light fraction materials can be revalued and reach more than a 95 % recycling level.

5.15 Comments on present methodologies

Once the content of the materials and present dismantling and recycling methodologies, the following observations reached.

- Most valued material is copper because it can be recycled endlessly without losing its performance. Copper is wrapped in wiring and is part of small connections. In analysed process, one of the problems that the light fraction presents are the presence of copper filaments of very short length, difficult to identify and separate.

- Third value stream of materials is plastic.

- Light fraction represents a small percentage of total weight, taking one unit as one vehicle.

- Different families of plastics are mixed. There is no valuable market for them.

- Out-sorting with purity these materials require high investment and new technologies.
- Metal’s segregation is automatized and has a high performance.

If iron is not considered, because it is a heavy and metallic fraction, which could be automatically segregated; this remaining bulk is 12,86 % weight of the vehicle.

Light fraction of ELV is quantified in % weight of the vehicle; main components have been identified; as well as the needs to revalue, recycle.

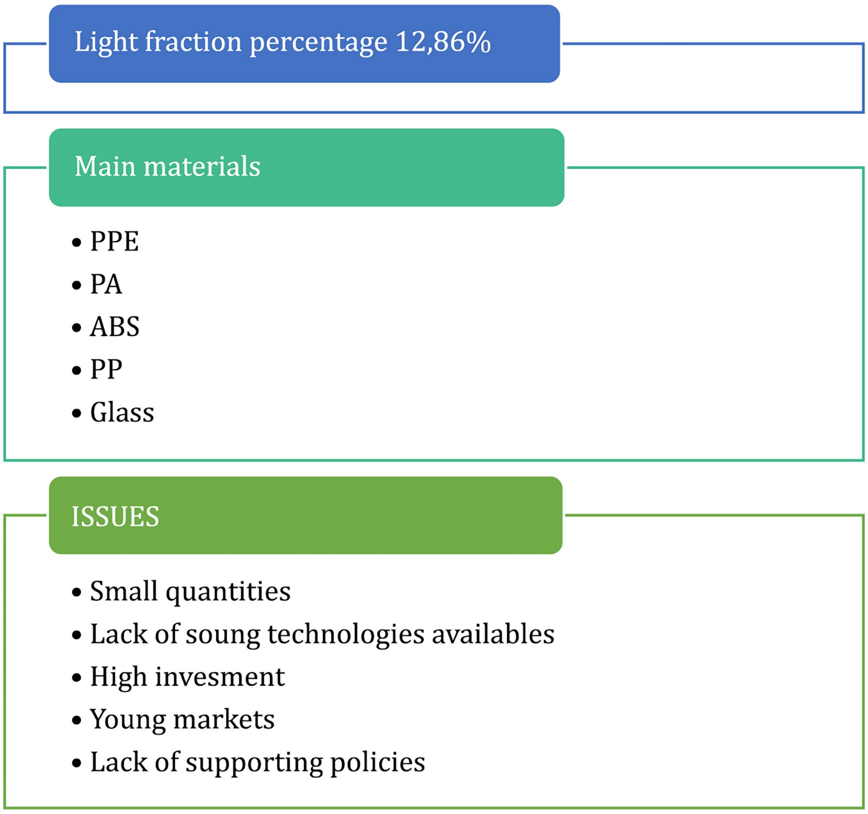

Figure 4 — Summary of light fraction characteristics

5.16 Evaluation of performance indicators

Under the afore mentioned premises (i. Avoid harm; ii. Reuse or recycle 95 % of material; iii. Valuable material) a questionnaire has been designed help making decisions when applying these protocols.

This questionnaire was based on evaluating three main areas: economic value of each part, circular economy approach for each part and other considerations, which could be particular for each case. For further information, see Annex A and Annex B.

It contains the good practices and lessons learnt along years of work. See Figure 5.

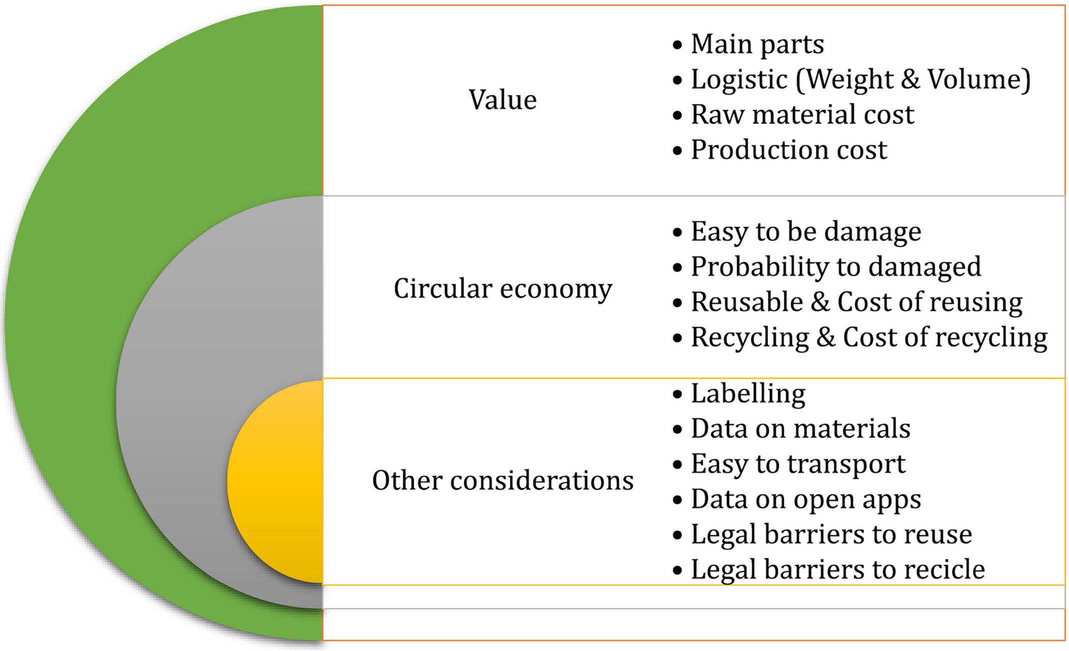

Figure 5 — Questionnaire concept

6 Dismantling Protocols

6.1 General

This protocol is a summary of good practises that have proven to produce positive results to deal with ELV in a circular economy framework. There may be different protocols also belonging to good practise classification, as the approaches to this problem can be carried out in many ways.

6.2 Recycling phases

When considering a recycling operation, it must be understood that the result is totally dependent on the correct handling of a number of phases:

1. Collection of worn and obsolete applications.
2. Disassembling and removal of non-compatible materials.
3. Sorting of different resins and grades.
4. Washing and grinding.
5. Quality checking, upgrading.
6. Conversion into quality-consistent material.

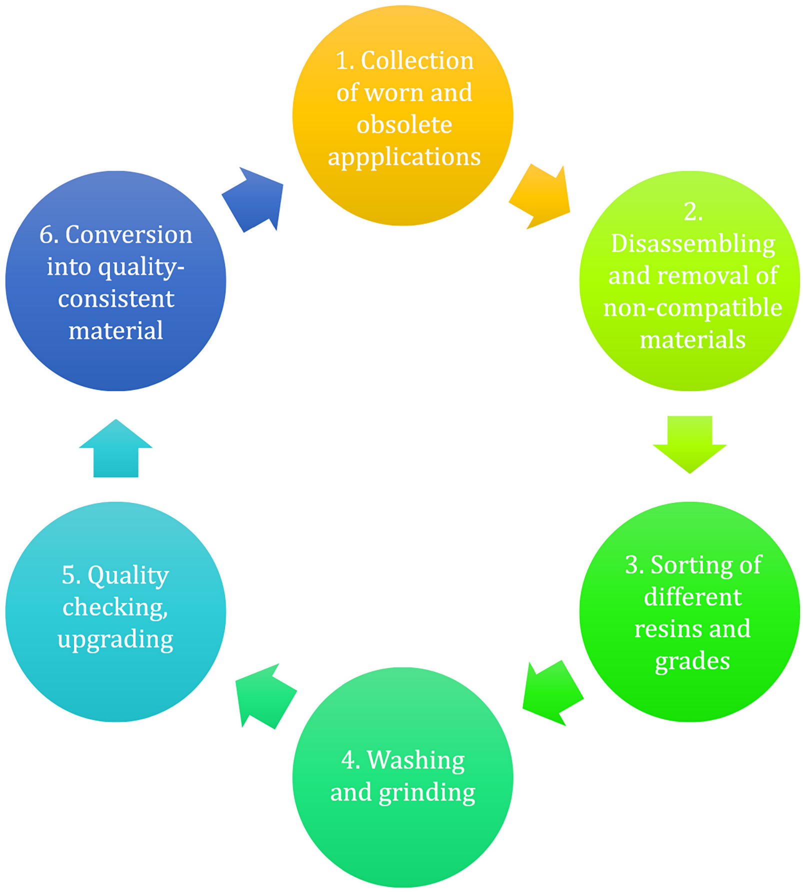

Figure 6 — Recycling phases

6.3 Economic recycling

Recycling must have a defined objective, central to which will be the establishment of the quickest, simples and lowest cost method of reclaiming useful and processible plastic materials. The principal economic element in this procedure is the time factor in combination with labour costs, particularly in respect of gathering, disassembling, and sorting operations. Key is the application being designed using a combination of compatible materials. The following factors will have a positive influence on the economic viability of recycling:

— Fast and logical gathering.

— Fast disassembly.

— Non-labour-intensive sorting.

— No cost or low-cost cleaning procedures.

— Increasing costs for deposition and incineration.

6.4 Relationship of product lifetime-recycling period

To analyse when and where the bulk of recyclable material can be expected to come from, it is useful to make an estimation of the average real lifetime of a range of applications and, therefore, the timeframe in which they will be disposed of.

6.5 Production/Recycling material flow-scheme

Design for recycling is essential if material is to continuously flow back through the system to fulfil further manufacturing needs. However, this can only be realised when everyone involved in the design and development of a new product, is fully aware of recycling principles and requirements. The choice of basic materials, appropriate design techniques and the optimal processing of a resin, all determine the result of the recycling process, technically and in economic terms.

6.6 Design for recycling

One of the main factors determining environmental responsible products is the capability of reusing its components in whatever form possible thereby reducing waste streams. A broader perspective is required in areas like:

— Residual functional and economical value of the materials and components with which he designs.

— Easy disassembling including the separation of non-compatible materials.

— Rapid safe sorting methods.

— Cleaning operations.

— Economics and form of preparation for reuse.

— Logistics of materials retrieval systems and possible interactions with other systems.

6.7 Design for easy disassembling

Design for disassembly is a key action within the “recycle friendly product” development phase, as optimal adaption of products will lead to:

— Easier material and component sorting.

— Reduced handling and labour.

— Improved overall economics.

— Waste reduction.

As paradoxical as it may seem to develop a product that is assembled to be easily disassembled, it requires an enlargement of perspective relative to traditional product design and engineering rather than a complete refocus on design methods.

6.8 Integration

Essentially one must strive for the highest degree of component consolidation technically possible, up to the limit where functionality requires different components. Using the possibilities offered by plastics for maximum integration, through their ability to form complicated parts, may lead to substantial reduction in part count and material mix or incompatible material combinations. Subsequent, positive effects will extend beyond the economy of assembly operations alone and result in improved disassembly operations, material recovery and related economics. Translating separate functional components into one main multi-functional part requires an “open minded” approach as radical redesign is often necessary.

6.9 Fixing systems

Disassembling must be realised with the minimum possible effort in every aspect. Speed and simplicity are key and are dominated by fastening methods, using their careful selection in the design phase. Within the selection criteria, automated disassembly should be considered as it typically also allows easy manual disassembly and facilitates future developments. Design in engineering plastics allows for the use of “push, hook and click” assembling techniques that are easily disassembled manually, with the aid of simple tools, or automatically.

Use of metal clamps, screws, inserts and other non-compatible assembly items should be avoided although this in not always possible. If applied, it is critical that these items are magnetic and easily accessible to facilitate ease of separation in any method applicable. Ideally fixings and fasteners should be designed in compatible materials whenever this is practicable.

6.10 Predetermined break areas

Good practice is to design in such a way that interconnection points and joints are easily accessible for opening, loosening, or separating no-compatible items by hand. Either with simple tools or automated systems. In those cases where irreversible “once-locked-never-to-open” connections or inserted non-compatible items are applied, “predetermined break areas” can be designed-in. These can also prevent “unauthorised” second use as the parts become irreparable after disconnecting.

6.11 Product layout

In “design for easy assembling” attention to the way products is laid-out is seen as one of the key focal points for successful rationalisation of assembling. Product layout also has great influence on the ease of disassembling, with subsequent positive effect on costs, making the need for its intensive study in the design phase even greater.

In general, the route is to design products allowing simple actions in assembling avoiding complex manipulation of parts, components, fasteners and modules thus, in reverse, leading to optimised disassembly. To accomplish this often requires a radical redesign of products into easily accessible building blocks or modules, which allows stacked or vertical products build-up with a minimum of manipulation. Typically, the modules are a chassis of some form acting as a carrier for additional components to be “dropped-in”. This “module” or “chassis” approach, from the design for easy assembly” guidelines, can be applied in conjunction with those given for “design for disassembly”.

6.12 Material mix reduction

It is common practice, for economic reasons, to use lower grade cost materials for less critical parts. However, the use of non-compatible materials may result in difficulty if not the impossibility of recycling, leading to possible cost penalties. The goal of material selection should be to reduce or even eliminate the need for the disassembly of a product in total by utilising compatible plastics. Although not always realistic for all products, it can however be achieved more easily for sub-assemblies within them. The strategy is to match all materials with the parts requiring higher performance characteristics. This “over-designing” will increase the initial cost of the product but may have an improved overall life cycle economy compared with traditional designs.

6.13 Welding

The use of welding techniques is well-known in the plastics industry, and the various systems available provide ample possibilities to join parts into a complete component. Although irreversible, thermal techniques like hot-plate, hot-gas, spin, vibration, and ultrasonic welding in most cases involve compatible materials therefore separation may not be required at all. With heat-staking, separation by breaking is often inevitable but as the connection are relatively weak it may, although not ideal, be applied.

6.14 Adhesive bonding/cementing techniques

If the previously mentioned techniques for joining plastic parts together cannot be used because of irregular joint shapes, bonding or cementing techniques are a frequent alternative. Solvent cementing techniques currently have an advantage, with respect to recycling, over bonding with secondary materials because the latter can cause heavy contamination or result in more complicated disassembling. However, when utilizing solvent bonding strict measures must be taken to prevent solvents entering the environment. Basically, only amorphous materials can be solvent cemented because of their solubility in certain solvents. With semi-crystalline materials it may be necessary to use adhesives techniques because of their inert chemical behaviour. When use of adhesives is unavoidable, it is advised to use compatible or reversible adhesives, to ensure that the sorting and recycling would be facilitated.

6.15 Secondary operations

Apart from the cleaning of dust and any adhering dirt, which can be done by washing or high-pressure cleaning, it is important to remove materials used for colouring, decoration, and information such as paints, metal plating, hot foil prints and stamped on textiles, etc. These operations are in many cases necessary to prevent material contamination thereby increasing of cost and complexity of the retrieval operations.

For aesthetic purposes it is common to use paints, foils, etc. also environmental protective paints, and coatings may be required. Most of these secondary finishes need to be removed unless they exhibit relatively low material deterioration effects due to compatibility or to low concentrations. Although advanced paint removal techniques are being developed, it is advisable to avoid painting and use the possibilities of “colouring-in” techniques, provided by plastics. Where special accents or shadow effects are desired in-moulded textures, reliefs and advanced ink diffusion techniques can be an alternative.

From a recycling point of view, metal plating of plastics can be considered a hurdle. Advanced removal systems utilizing mechanical, electro-chemical and ultrasonic cleaning techniques are being developed with high priority in conjunction with industry and these will provide a benefit for the future.

Decorations or instructions are often presented by means of adhesive labels, hot-foil prints, etc. Depending on the type of adhesive it is generally possible to remove these non-compatible labelling systems by chemical or mechanical methods. Less costly is the use of adhesives which are water soluble which is especially applicable for reusable items like bottles. Alternatively, one may use “pop-in-pop-out” labelling which can be separated more easily or moulded-in reliefs and which are particularly applicable for instructions on equipment.

6.16 Design for rapid, safe sorting

6.16.1 General

To be assured of perfect batches of material for recycling it is necessary to be able to easily sort the plastic parts after gathering and disassembling. Different methods can be applied and are already used by manufacturers to identify and distinguish the plastic parts and the material they are composed of. A system for material identification should be thoroughly considered before it is adopted, as any subsequent change in methods will cause disruption to sorting facilities. Several identification methods are presented here, ranked most to least preferred.

6.16.2 In-mould coding

This method of material identification should always be used as it not only allows easy sorting but also provides the possibilities of adding specific material descriptions. The codes of symbols, designating the plastic used, could follow standards such as EN ISO 1043 (Serie), DIN 6120, VDA 260 or SAE J1344. These should be engraved in the mould and reproduced on a non-appearance surface pf the product but still easily readable.

6.16.3 Bar coding

This method is currently under development and may eventually lead to a system for fully automated part and material sorting. The information is added to the parts via in-moulding in the form of a relief or via laser-marking techniques currently being developed. The resultant bar code information can be read by machine.

6.16.4 Colour coding

Colour coding can be realised by having within one assembly, all parts made from the same resin or grade in an identical colour. This method is only relevant for on product recycling stream as it is not fool proof when interaction exists with other relative non-controllable ones. It should be considered an additional aid in sorting rather than an identification system.

7 EC Policies on Circular Economy

7.1 Overview

7.1.1 Managing the life cycle of natural resources

Managing the life cycle of natural resources, from extraction through the design and manufacture of products, to what is considered as waste is essential to green growth and part of developing a resource-efficient, circular economy where nothing is wasted. Smarter design allowing products to be repaired, re-used, remanufactured, and then recycled again should become the norm.

7.1.2 It is good for business, citizens, and nature.

The European Commission promotes resource efficiency, encourages eco-innovation, provides tools that can help you recognize green products and supports eco-friendly, innovative businesses.

7.1.3 A greener economy means new growth and job opportunities

Eco-design, eco-innovation, waste prevention and the reuse of raw materials can bring net savings for EU businesses of up to EUR 600 billion. Additional measures to increase resource productivity by 30 % by 2030 could boost GDP by nearly 1 %, while creating 2 million additional jobs. It also benefits the environment and reduces Europe's greenhouse gas emissions.

The Europe 2020 Strategy is the Commission's strategy for smart, inclusive and sustainable growth. The Commission actively supports businesses, administrations, and consumers so that together, we can turn the Union into a resource-efficient, green, and competitive low-carbon economy. This is one of the three objectives of the 7th Environment Action Programme. To get growing again and create new jobs, while contributing to the global Sustainable Development Goals, Europe cannot afford to waste this opportunity.

Circular Economy Package: The Commission has adopted a package of measures and legislative proposals to boost sustainable growth and help Europe make the transition towards a more circular economy.

7.1.4 Revise the rules on end-of-life vehicles to promote more circular business models.

The CEAP (Circular Economy Action Plan) also announces that “the Commission will also propose to revise the rules on end-of-life vehicles with a view to promoting more circular business models by linking design issues to end-of-life treatment, considering rules on mandatory recycled content for certain materials of components, and improving recycling efficiency.”

7.2 EU Circular Economy Action Plan

A new Circular Economy Action Plan for a Cleaner and More Competitive Europe. The European Commission has adopted a new Circular Economy Action Plan — one of the main blocks of the European Green Deal, Europe’s new agenda for sustainable growth.

The new Action Plan announces initiatives along the entire life cycle of products, targeting for example their design, promoting circular economy processes, fostering sustainable consumption, and aiming to ensure that the resources used are kept in the EU economy for as long as possible.

It introduces legislative and non-legislative measures targeting areas where action at the EU level brings real added value.

7.3 Actions

The new Circular Economy Action presents measures to:

- Make sustainable products the norm in the EU.
- Empower consumers and public buyers.
- Focus on the sectors that use most resources and where the potential for circularity is high such as: electronics and ICT; batteries and vehicles; packaging; plastics; textiles; construction and buildings. food; water and nutrients.
- Ensure less waste.
- Make circularity work for people, regions, and cities.
- Lead global efforts on circular economy.
- Revise the rules on end-of-life vehicles to promote more circular business models.

In 2021, the European Commission is launching its new Green Consumption Pledge, the first initiative delivered under the New Consumer Agenda. The Green Consumption Pledge is part of the European Climate Pact which is an EU-wide initiative inviting people, communities, and organizations to participate in climate action and build a greener Europe. The Green Consumption Pledge is based on a set of five core pledges: Calculate the carbon footprint of the company. These are: calculate the carbon footprint of selected flagship products, increase the sale of sustainable products or services, commit part of the corporate public relations expenditure to the promotion of sustainable practices, and ensure information provided to consumers in relation to the company and product carbon footprints.

7.4 Automotive plastic trends

It is currently more difficult to introduce new materials into the automotive industry than was previously the case[2]. Suppliers are looking for cost-efficient methods, while new materials frequently call for new machines and other investments in the production process.

Plastics are raising challenges as well. In addition to competing as an often less expensive alternative to steel and aluminium, and as a constantly developing material, plastics are affected by volatile oil prices and variable production volumes. Because of these factors, the market is characterised by considerable uncertainty.

Despite these global obstacles, the many advantages of plastics have earned them a place in the automotive market. The sustainability and performance characteristics of fibre-reinforced plastics are particularly attractive to European car manufacturers.

7.5 Environmental trends

One of the most prominent trends in the automotive industry involves making vehicles lighter, thereby reducing their emissions. Heavy-weight steel parts are being replaced by lightweight composites, carbon fibre, glass fibre and other plastics. Although the source is not renewable, the production process itself is more efficient in terms of energy, as compared to steel.

Recycling is another issue in the automotive industry. Despite the industry’s excellent record around recycling, reuse and recycling are presenting challenges in the use of all thermoset plastics. European regulations require a high rate of re-use and recycling for each vehicle. Importers are therefore likely to exercise considerable caution when importing thermoset plastics.

7.6 Trends involving quality

Simply recycling plastics reduces the purity and performance of the material. In recent years, however, fibre-reinforced plastics have been introduced, combining the material characteristics and cost-competitiveness of steel with the recyclability and lightweight characteristics of plastics. For example, natural-fibre composites are currently being used for interior door trims. Wood-plastic composites are used for the rear shelf, as well as for the trunk and spare wheel trims.

Roof liners and dashboards are often made of fibreglass-reinforced composites. Pure plastic is used for interior door trim, pillars, and trunks. In addition to their sustainability features, fibre-reinforced plastics offer advantages regarding performance.

Developments in the crash performance and resistance of plastics have made safety an area in which considerable progress could be achieved. In addition, the flexibility of the material is quite welcome in terms of aesthetics, while its stiffness makes plastics suitable for optimising long-term passenger comfort.

Future market developments for natural-fibre reinforced composites remain difficult to predict, as

[2]) *Reference to Plastic Fact Sheet.*

estimates vary widely.

Nevertheless, natural-fibre composites have clearly become an integral part of the industry, and they continue to develop in terms of strength, crash performance and stiffness, while remaining light in weight.

7.7 New strategies to implement

7.7.1 General

An overview of conclusions applicable to all cases, can be summarized in 6 key areas that are undergoing a massive transformation in the waste management industry[3)].

7.7.2 Improved Recycling Rates

Recycling and waste management companies are investing in improving their tools and techniques. The recent development in single-stream recycling where people can dump all the trash in one bin has reduced the sorting burden on people and drastically improved the rate of recycling. This has also reduced the truck count and ultimately the emissions as well.

7.7.3 Automated Waste Collection

Technology has transformed the way waste management works with automated sensors that trigger instant alerts every time a container is full and needs service. Other innovative tools that are making the sorting process fast and easy include optical sorters, magnets, and advanced disk screens. The trucks have also switched from diesel to natural gas for quieter and cost-effective operations. The use of logistics software, in-vehicle monitors, and mobile apps has further simplified the waste management process while ensuring driver safety.

7.7.4 Route Optimization

Optimal routing is essential to protecting the environment and reducing hazardous emissions which is why companies are investing in advanced systems and optimization software. They are now employing automated trucks that are installed with robotic arms for saving time and effort along existing routes. Technology has made point-to-point pickups eco-friendly and financially viable while improving energy-efficiency.

7.7.5 Landfill Minimization

Although landfill is almost impossible to reduce to extinction, a remarkable minimisation should be a trend, as materials once they have reached this destiny are hard to revalorise. A policy to boost the revalue of any material should be part of the strategy.

7.7.6 Enhanced Safety

Recycling and waste management companies are making consistent efforts to improve safety which is of prime importance to an industry running several 30-ton trucks through residential areas. All their drivers are subjected to rigorous training at designated facilities to reduce the rate of accidents and injuries.

7.7.7 Quick Turnaround Times

Bigger waste management companies have also invested in feature-rich customer-facing technology. They are leveraging user-friendly mobile apps to facilitate prompt service, extra pickups, and bill payment through push notifications. Technology has greatly reduced the complexity and cost of modern-day waste management systems making them more efficient, safer and productive while reducing their environmental impact.

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3) *Reference to specialised companies.*

Figure 7 — Strategies to implement

7.8 Automotive sector conclusions

The recycling of plastics has thus become a hotly discussed and sometimes controversial subject of political, industrial, and public debate. To work out solutions that will be acceptable to all sides, however, requires an objective look at the options and limitations of plastics recycling.

The legislation on the recycling of scrap vehicles will require manufacturers and retailers to reclaim vehicles and recycle their component materials. The aim is to carefully disassemble scrap vehicles and thereby pinpoint means of recycling the used plastics components. A key prerequisite for high-grade recycling is a marking system for identifying and sorting the different types of plastics used in vehicle components.

This work is aimed at finding secondary applications for quality-assured recycled plastics, primarily in the sector in which they were used, in this case the automotive industry. In addition to this, other efforts are focusing on logistics and the preparations for recycling, such as identification, coating removal and stabilisation.

The intensive efforts that have gone into the recycling of plastic automotive components show that single-sort plastics components can be readily recycled. However, for logistical reasons (identification, sorting) and on economic grounds (dismantling intensity, preparation into single sort regrind), only selected parts should be dismantled. The other components remain in the car body and make up the shredder fluff which emerges after shredding.

Apart from the aspects of technical feasibility, which have been the main aspects considered here, there are also economic and ecological aspects to be borne in mind. We cannot opt for recycling if the costs are too high. The percentage of plastics products that cannot be re-used must be drastically reduced. The experience and findings that we gain in the material recycling of plastics (including those cases where material recycling is not yet economically viable) thus represent a fundamental prerequisite for the development of materials, processes and products for the future which are optimised in recycling terms.

It is not uncommon for incompatible plastics to be combined in automotive components, and many cases completely different materials are used for the same components of different models in one and the same range. In addition, accessories and spare parts were often moulded in different materials again. This intermingling of grades and the presence of hazardous substances is currently presenting many problems in the material recycling of plastics from scarp cars.

The current practice of marking materials according to type, the automated plastics identification and sorting methods which are at present under development, and additional separation methods will help to make the task of recycling plastic components much easier.

Efficient assembly techniques are an essential feature of cost-effective component design. Apart from component assembly, consideration must also be given at the design stage to cost-efficient dismantling.

The dismantling operation is not simply the assembly operation in reverse. Different constraints prevail during dismantling. Consideration can also be given to dismantling techniques which destroy the component. Many dismantling tests, however, have revealed destructive techniques to be generally less efficient than selective dismantling.

Snap joints that are readily accessible and can easily be undone with standard tools not only offer enormous advantages when it comes to repairs but are also ideal for subsequent dismantling.

One important factor is that persons who are not familiar with the unit in question should be able to readily identify the possibilities it offers for dismantling.

Annex A
(informative)

Questionnaire

Below you can see the Template of a questionnaire to evaluate recovered parts according to i) economic costs, ii) circular economy model; and iii) other considerations as legal barriers or traceability.

ECOBULK		Value Scales (1 the lowest to 10 the highest value)				
PART	Main parts in your prototype	Weight	Volume	Raw material cost	Production cost	Comments
1						
2						
3						
4						
5						
6						
7						
8						
9						
				0	0	0

Circular economy Scales (1 the lowest to 10 the highest value)								
Parts	Main parts in your prototype	Easy to be damaged	Probability to be damaged	Reusable	Cost of reusing	Recyclable	Cost of recycling	Comments
1								
2								
3								
4								
5								
6	0							
7	0							
8	0							
9	0							
10	0							
Total	5	0	0	0	0	0	0	0

		Other Scales (1 the lowest to 10 the highest value)						
Parts	Main parts in your prototype	Labelling	Data base on materials	Easy to transport	Data base on applications	Legal barriers to reuse	Legal barriers to recycle	Comments
1								
2								
3								
4								
5								
6								
7	0							
8	0							
9	0							
10	0							
Total	0							0

Annex B
(informative)

Questionnaire´s Conclusions

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