TREASURE

D1.3: Industrial use cases and scenarios design (1st version)

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RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

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EXECUTIVE SUMMARY

The main aim of the TREASURE project is testing innovative technologies to make the automotive sector more circular. To this aim, TREASURE wants to implement an AI-based scenario assessment tool supporting the development of circular supply chains in the automotive sector. Through a set of success stories coming from the application of circular economy principles in three key automotive-related value chains, TREASURE wants to demonstrate in practice the real benefits coming from the adoption of circular behaviours. In addition, Key Enabling Technologies (KETs) will be integrated within the selected processes to support the efficient design of car electronics and its subsequent disassembly and materials recovery.

Deliverable 1.3 “Industrial use cases and scenarios design” is one of the two deliverables related to activities done in Task 1.3 within WP1 “Reference Framework definition”. The objective of D1.3 is to summarize the list of industrial requirements gathered from TREASURE’s industrial actors during dedicated workshops, basing also on key inputs coming from D1.1 (TREASURE reference framework). A second deliverable (named D1.4 - expected at M18) will add details about each use case in terms of validation targets and related KPIs. Starting from them, some detailed specifications for the development of the demonstrators (WP6) will be laid down, by establishing boundaries and main goals characterizing the TREASURE solution and its integration within the different pilots.

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1. Introduction

Starting from the findings reported in D1.1 by SUPSI, D1.3 wants to better specify the different activities that will be implemented in each use case. The intent of this document is, hence, to present each use case in detail by following a standardized logic and identify the related requirements. The final purpose of these use cases is bringing together knowledge, tools and technologies developed in other WPs and demonstrating their benefits into practice, by covering three different stages in the automotive value chain. To this aim, the reference logic adopted for the description of each use case comes from the Circular Car Initiative (CCI) report on circular business models in the automotive sector[2].

1.1. Scope of the deliverable

D1.3 "Industrial use cases and scenarios design" is the deliverable associated to Task 1.3 focused on the description of the TREASURE's industrial use cases. Starting from the findings provided by Task T1.1 and building upon the platform's requirements gathered and formulated in compliance to Task T1.2, D.3 provides a preliminary overview of the TREASURE industrial use cases. A more detailed description of the TREASURE industrial use cases will follow at M18.

Working together with Task 1.2, the use case scenarios have been analysed, deeply investigating how the TREASURE solutions could support the transition from the AS-IS to the TO-BE scenarios. Hence, this deliverable identifies the different scenarios to be implemented considering the targeted stakeholders and include the business requirements to give an overview of the current needs that stakeholders have and to which the TREASURE project should provide a solution.

The whole industrial use cases implementation will be split into two work packages. Within WP5, a set of lab-scaled activities will identify the most suitable solutions to implement. In addition, these solutions will be optimized to treat automotive components and materials. Within WP6, the available solutions will be tested together with the TREASURE industrial partners, by comparing the benefits coming from their adoption with current performances (especially in terms of sustainability and circularity).

1.2. Contributions to other WPs

This deliverable belongs to WP1 "Reference framework definition" and it identifies the different scenarios to be implemented considering the targeted stakeholders and includes the business requirements to give an overview of the current needs that the stakeholders have and to which the TREASURE platform should provide a solution. Moreover, the document provides an initial overview of the industrial use cases that will be developed within TREASURE, and it will connect the industrial use case perspective with the TREASURE platform's requirements described in T1.2. Therefore, this deliverable is directly related to the following work packages:

- <u>WP5 "Pilot plants reconfiguration/optimization"</u>: D1.3 collects the industrial use cases requirements and provides an overall picture of the pilots and their testing environment.
- <u>WP6 "Validation & demonstration"</u>: D1.3 mainly provides an initial scenarios definition in order to set up the different validation & demonstration activities together with the industrial partners involved in TREASURE.

[2] https://www.weforum.org/reports/raising-ambitions-a-new-roadmap-for-the-automotive-circular-economy

1.3. A reference logic to describe the TREASURE's use cases

1.1.1. The CCI report-like pilot project idea table

Considering the aforementioned CCI report, each pilot project idea related to CCI activities has been classified basing on their transformation pathway, or the way they contribute to the adoption of Circular Economy (CE) in the automotive sector. The identified transformation pathways have been identified in: a) energy decarbonization, b) material circularity, c) lifetime optimization and d) utilization improvement. Basing on these typologies, each pilot project idea has been subsequently specified. Hereafter, it is reported a table showing the type of information identifying each action.

Figure 1 - CCI report-like pilot project idea details

Solution: • XXX	**Transformation pathway:** • XXX	**Impact on measures:** • XXX • XXX

Pilot objective: • xxx	Enablers & synergies: • xxx
Benefits: • xxx	Owners & contributors: • Owner: xxx • Contributors: xxx
Barriers: • xxx	Next steps: 1. Xxx 2. Xxx 3. Xxx 4. xxx

Within the previous table, each pilot project idea has been described by CCI in terms of:

- **Solution**: a reference name of each pilot project idea.
- **Transformation pathway**: a map of the relations of each pilot project idea with the overall circular strategies identified by the CCI.
- **Impact on measures**: a list of impacts identified by the CCI that are somehow linked with each pilot project idea.
- **Objectives**: the main objective of each pilot project idea.
- **Benefits**: a list of benefits expected from each pilot project idea.
- **Barriers**: a list of barriers to be coped with by each pilot project idea.
- **Enablers & synergies**: a list of factors (e.g. technologies, systems, procedures, etc.) that could be exploited by each pilot project idea.
- **Owners & contributors**: pilot project team leaders (owners) and a list of actors involved in each pilot project idea (contributors).
- **Next steps**: a list of future activities to be implemented by each pilot project idea.

One of the intents of D1.3 is trying to define a similar table to be adopted in TREASURE to map each use case and relate it with circular strategies identified in the CCI report.

1.1.2. The TREASURE use case description table

Starting from the information fields related with the previous Figure 1, TREASURE defined a similar table in order to classify and monitor the different use cases developed during the project. Within TREASURE, each use case will be mainly classified basing on its objective, use case team and expected impacts. Then, each use case will be specified in terms of requirements,

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specifics, platform-related boundaries and goals, validation targets, evaluation procedures, activities and KPIs. Each of these fields will be described below. The main difference between the TREASURE use case description table and the original CCI one lies in the level of detail. The CCI table tries to generically link each pilot action with the CCI classification logic (widely described in their report). Instead, the TREASURE use case description table intends to summarize and make evident the link between each use case, the TREASURE platform and the different sustainability and circularity assessment logics and tools developed within the project. The voluntary choice of starting from an already existing logic, will allow TREASURE to easily match its activities with the implementation strategies identified by the CCI report.

After an initial evaluation of the possible matches between Figure 1 and requirements coming from the T1.3 description embedded in WP1, a new table has been developed and assessed by TREASURE industrial partners in a dedicated workshop. The new table is reported below.

Figure 2 – The TREASURE use case description table

Objective: • XXX	**Owner & contributors:** • XXX	**Expected impacts:** • XXX • XXX

Industrial requirements: • Xxx	Use case specifics: • Xxx
TREASURE platform integration boundaries: • Xxx	TREASURE platform integration goals: • Xxx
Validation targets: • Xxx	Evaluation procedures: • Xxx
Activities: 1. Xxx	KPIs: • Xxx

All the information reported in Figure 2 are strictly related with TREASURE and its activities. Specifically:

- **Objective**: the main objective related with each use case. Within TREASURE, the objective can be: a) improving car electronics disassembly performance, b) improving car electronics recycling performance and c) improving the eco-design of IMSE prototypes for new automotive applications.
- **Owner & contributors:** a brief description of the selected owner of each use case (e.g. POLLINI-disassembly, ILSSA-disassembly & recycling and WALTER-flexible electronics) and the contributing partners.
- **Expected impacts:** a list of impacts related with each use case identified by the consortium. They can be considered as a sub-section of the “impact on measures” field coming from the CCI report.
- **Industrial requirements**: a list of industrial requirements identified by the industrial partners involved in each use case.
- **Use case specifics**: a description of each use case structure and existing pilots to be exploited during validation and demonstration activities.
- **TREASURE platform integration boundaries**: a list of boundaries identified by the consortium to be considered during the development of the TREASURE platform. These boundaries can be represented by either information gaps, information sharing permissions, database access restrictions, etc. (provided in D1.2).

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- **TREASURE platform integration goals**: a list of goals identified by the consortium to be reached at the end of the project through the TREASURE platform. These goals are directly related to either KPIs & methodologies identified in WP2, and value chain digitalization modules identified in WP3 (provided in D1.2).
- **Validation targets:** in parallel with integration goals, they are directly related to practical use case activities and industrial requirements. They represent an approximative measure of how much the industrial requirements have been met.
- **Evaluation procedures:** a list of procedures adopted by each use case team to monitor their activities.
- **Activities:** a list of activities to be implemented in each use case.
- **KPIs:** a list of operational KPIs to be measured in each use case. They are directly related to both the evaluation procedures, WP2 and WP3 activities.

Within the first version of this deliverable, only the points 1-5 of the previous bullet list will be described in the following sections. Points 6-7 will be widely described in D1.2. Finally, points 8-11 will be described in the second version of this deliverable (named D1.4 - expected at M18).

2. Participants and facilities

The following table provides a comprehensive description of the involved partners and the list of facilities that are going to be exploited in each use case.

Table 1 – List of partners and facilities in each use case

ID	Location	Leader	Involved partners	Reference facility
DIS	ITA	POLIMI	POLLINI, TXT, MARAS, SEAT, EUROLCDS	POLIMI's I4.0 Lab
REC	ITA	UNIVAQ	EUROLCDS, TXT, MARAS, SEAT, ILSSA, UNIZAR	UNIVAQ's pilot plant
ECO	NED	TNO	WALTER, TXT, MARAS, SEAT, EUROLCDS	TNO's Lab

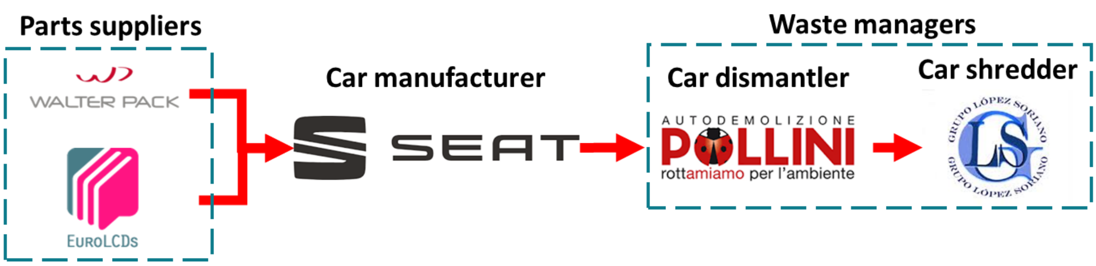
ID detailed description:

- **DIS:** Italian use case on car electronics disassembly
- **REC:** Italian use case on car electronics material recovery
- **ECO:** Dutch use case on in-mold/structural electronics eco-design

2.1. TREASURE actors' value chain

The following picture describes the role of each TREASURE's industrial partner involved in each of the previous use cases within the automotive value chain.

Figure 3 – The TREASURE's automotive value chain



2.1.1. WALTER

Company description: WALTER has its head-office in the Basque Country, a region in the north of Spain globally known for its industrial tradition. WALTER began producing thermoformed plastic parts for a wide variety of industrial sectors and has been taking over and building up around it a group of companies focused on the provision of comprehensive solution services and the manufacture of plastic parts, with the automotive industry being one of its main customers and the force behind all the company's innovation processes. In 2000, the company embarked upon an ambitious globalization plan, with the first steps being taken to open a production unit in India (2008), targeting the Asian market, as well as a plant in Mexico (2015) to serve the Americas. In 2016, it reinforced its presence in Asia with a second plant in India (Delhi). In 2014, WALTER took another step forward by taking over the Catalan company PPT, a world leader using IMF technology in the manufacture of decorative plastic parts for the automotive industry, and a TIER 1 supplier for several brands. WALTER's core business is to supply decorative parts for the automotive, electronics and household appliances industries. As a worldwide expert in Film Insert Moulding technology (FIM, an advanced process based on screen printing, thermoforming, trimming and back-moulding of plastic foils), WALTER is currently developing "plastronics" technology, which besides state-of-the-art decoration applications, it now incorporates functional electronics into the finished part. This adds functionality to the parts and reduces both the cost of assembly processes and the space used by standard electronics.

Facilities involved in TREASURE: WALTER production facilities @ Igorre – Basque Countries (Spain).

2.1.2. EUROLCDS

Company description: EUROLCDs is a European SME, the manufacturer of the liquid crystal displays, specializing for prototyping of novel display products and niche production of light shutters, diffusers, and other photonic elements. It offers manufacturing capabilities within more than 1800 m^2 large clean room facility using automated liquid-crystal display processing line. The manufacturing operation of EUROLCDs mostly is in tandem with connected group company HansaMatrix. HansaMatrix has PCB and electronics contract manufacturing plant next to EUROLCDs. EUROLCDs production line was used for mass production of European automotive displays in Babenhausen, Germany until 2011, when it was moved to Latvia and transformed into pilot line for novel display types, including but not limited to, tuneable liquid crystal lenses for headlights, smart car windows and 3D volumetric and Augmented Reality car infotainment systems.

Facilities involved in TREASURE: EUROLCDS clean room with mixed ISO6 and ISO7 cleanness levels @ Ventspils (Latvia).

2.1.3. POLLINI

Company description: POLLINI operates in the automotive sector as authorized dismantling centre for 40 years, involving 3 generations. During the years, experience and passion for work allowed to widen the company, by reaching an overall operation area of about 55.000 m^2. Nowadays, our team is composed by 100 workers located in 5 plants on the strategic axe Verona-Milan. Proud of our professionality and seriousness, we are continuously investing in research and development to maintain a high customer satisfaction and a high competitiveness in the market.

Facilities involved in TREASURE: POLLINI headquarter @ Bedizzole – Brescia (Italy).

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2.2. TREASURE components/materials value chain

Within WP3 (specifically T3.1), five car electronics components selected by SEAT through a thermodynamic rarity analysis (e.g. infotainment unit, dashboard - combi meter, third brake light, external electric rear view mirrors and sensors – specifically, air quality sensor, rain sensor, speed and ABS sensor) + plastic components (e.g. clima module and middle console) extracted from two SEAT models (e.g. IBIZA GEN4 and LEON GEN2/3 – both gasoline and diesel versions) will be considered.

Table 2 – Car electronics components considered in TREASURE

	Reference MISS codes		
Component	**Leon II**	**Leon III**	**Ibiza IV**
Infotainment unit	5P0.035.186.B	5F0.035.871.B	
Combi-Instrument	1P0.920.850.H	5F0.920.741.D	6J0.920.806.C
Air condition unit	1K0.010.328.J	5QF.010.008	6R0.010.818.E
Exterior mirrors	1P1.857.501.AC	5F1.857.501.AE	6J1.857.501.N
Additional break lighting	6J4.945.097.C	5F0.945.097.D	6J0.945.097.A
Speed sensor	WHT.003.857	WHT.003.860	WHT.003.863
Rain sensor	1P0.955.559.A	8U0.955.559	Not available in MISS
Interior air quality sensor		5Q0.907.643.C	Not available in MISS

Figure 4 – SEAT car models considered in TREASURE

Both SEAT models and car components to be removed have been specified in the deliverable D3.1 in terms of their main sub-parts and materials composition. Within TREASURE, car electronics components initially disassembled from cars by ILSSA will be furtherly disassembled in the DIS use case by POLIMI's PCB semi-automated disassembly station. Then, either whole

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Printed Circuit Boards (PCBs) or specific electronic parts (e.g. microchips extracted from PCBs) will be sent to the REC use case for being treated by the UNIVAQ's hydrometallurgical pilot plant in order to recover valuable materials (e.g. Ag and Au). Plastic components, instead, will be directly managed by the REC use case in order to recover polymers.

2.3. Use cases positioning

Considering the previous Figure 3, the use cases developed in TREASURE can be classified as follows. Firstly, DIS will consider the car electronics disassembly. To this aim, the use case is positioned at End-of-Life (EoL) stage, precisely in the waste management side of Figure 3. Secondly, REC will consider car electronics materials recovery. Again, this use case can be positioned at EoL stage, precisely in the waste management side of Figure 3. Finally, ECO will consider in-mold/structural care electronics eco-design. Differently from all the previous ones, this is the only use case that can be positioned at Beginning of Life (BoL) stage, focusing on the middle between car parts suppliers and carmakers (see Figure 3), linked to EoL management.

3. Industrial use cases and scenarios design

Within the TREASURE project, three industrial use cases have been identified. They are related to car electronics disassembly, car electronics recycling and eco-design of IMSE prototypes for new applications (possibly in the automotive sector). Within this section, these use cases will be described into detail basing on some of the fields reported by the TREASURE use case description table. Basing on what reported by the DoA, the lacking fields will be described in D1.4 (expected at M18). In addition to the TREASURE use case description table's fields, a description of the AS-IS and TO-BE scenario has been annexed to each use case.

3.1. Car electronics disassembly processes (DIS use case)

3.1.1. Objective

The first use case (named DIS) refers to car electronics disassembly processes. Like previously described in section 2.2, DIS will consider the five car electronics components selected by SEAT (see Figure 5 below and D3.1 for details) and manually disassembled from ELVs by ILSSA (see Figure 5 below and D3.2 for details). Within the DIS use case, the disassembly of car electronics will go ahead, by desoldering valuable electronic components (e.g. microchips, capacitors, diodes, etc.) from PCBs. This activity will be executed by POLLINI (supported by POLIMI and TXT). Specifics about the PCB semi-automated disassembly process adopted in TREASURE will be given in WP5 deliverables.

Figure 5 – Links between WP3 activities and the DIS use case

AS-IS scenario

The current state of car electronics disassembly processes can be briefly described. Given the absence of both a dedicated European/national regulation imposing its extraction from ELVs and a dedicated market for obsolete car electronics components (and related secondary materials), none of the actors involved in ELV management practices do that spontaneously. The general view of the interviewed actors on this topic is that this is an anti-economic procedure. Hence, these components are not disassembled from ELVs, finishing to be shredded together with the rest of the car. This behaviour has been already identified by the scientific literature (Cucchiella et al., 2016; Rosa and Terzi, 2018, 2016) as a big economic loss for the entire automotive value chain both in terms of lost profits for dismantlers/shredders/materials recovery plants and lost volumes of secondary materials/spare parts that could have been re-introduced either in the automotive or related value chains. This issue makes also evident the low circularity level of the automotive sector in terms of critical materials recovery from car electronics. Again, all these wasted materials (especially precious and critical ones) have a high negative impact in terms of natural resources depletion (particularly important at political level). Finally, considering the current semiconductor crisis in the automotive sector, the incorrect management of car electronics components sounds like a big paradox.

AS-IS Challenges

- The mass-based logic followed by the ELV Directive disincentivises scarce metals recovery
- Absence of a European/national regulation on car electronics EoL management
- Old tradition/way of doing of car dismantlers/shredders act against investments in new technologies/processes
- General perspective of car electronics EoL management as a labour intensive/costly (manual) procedure
- Relevant depletion of valuable/critical resources embedded in car electronics
- Relevant economic loss for the entire automotive value chain
- Low circularity of the automotive value chain in terms of critical materials recovery due to their relative minor presence in comparison to entire car mass

3.1.2. Owners & contributors

- POLIMI (university) will implement a semi-automated PCB disassembly process
- POLLINI (car dismantler) will test the POLIMI’s solution
- SEAT (carmaker) will support both POLLINI by sharing data on its car models and related components & materials
- TXT (ICT consultant) will support both POLLINI by implementing a dedicated module in the TREASURE platform
- MARAS (sustainability consultant) will support POLIMI and TXT by sharing knowledge and recycling figures coming from its recycling simulation models
- ILSSA (car dismantler) will supply car electronics manually disassembled from ELVs and related information (e.g. disassembly times, weight, embedded materials)
- EUROLCDS (LCD manufacturer) will support POLIMI by supplying both PCBs to be disassembled and related information (e.g. components identification, CAD files).

The scientific responsibility of the use case on car electronics disassembly processes will be in the hands of POLIMI (DIS scientific leader). The technical responsibility will be in the hands of POLLINI (DIS leader).

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3.1.3. *Expected impact (TO-BE scenario)*

One of the main intents of TREASURE is trying to increase the awareness of the different actors involved in automotive value chains about the value embedded in car electronics components and the importance of their correct recovery. To this aim, each use case will be focusing on both a specific EoL process stage and I4.0 technology in order to increase the circularity performance of the whole sector. In terms of car electronics disassembly, we can describe the DIS use case from different perspectives. Firstly, within the TREASURE consortium there are two partners acting as car dismantlers (ILSSA and POLLINI) from two locations (Spain and Italy). This way, there could be a direct comparison in terms of both disassembly performances/procedures (e.g. by exploiting WP2 and WP3 results – see Table 3). Secondly, within TREASURE there will be the chance to assess the impact of I4.0 technologies adoption in current ELV management processes. Under this term, POLLINI (together with POLIMI) will combine fully manual disassembly operations with a semi-automated disassembly process (by exploiting WP5 results - see Table 3 and 4) dedicated to automotive Printed Circuit Boards (PCBs). Finally, POLLINI will be supported by a specific module of the TREASURE platform developed by TXT, the "Disassemblability module" (see Table 4). This module will A) provide information on critical and valuable car parts to be disassembled, B) provide useful disassembly instructions, C) increase the awareness of carmakers/car parts suppliers about the recovery of critical materials from ELVs, D) increase the information/knowledge sharing between car parts suppliers/carmakers and different actors managing ELVs, E) measure/calculate the effects of disassembly intensity on recycling performance through the recycling simulation models, F) quantify the improvement of minor/critical elements recovery through disassembly.

Table 3 – List of applied results from previous WPs & Tasks in the DIS use case

Applied results from other WPs/Tasks	WP	Task	Task Leader
Sustainability & circularity assessment methods and KPIs	WP2	T2.1, T2.2	SUPSI
Disassemblability analysis, guidelines & integration with CE indexes	WP3	T3.1, T3.2, T3.4	SEAT, ILSSA, UNIZAR
Simulation, lab-scale tests & optimized disassembly procedures	WP5	T5.1, T5.2	POLIMI

Table 4 – List of reference modules and technologies applied in the DIS use case

Reference TREASURE platform's module
Disassemblability module
Reference technology/asset
POLIMI's PCB semi-automated disassembly cell (ref. FENIX project)

3.1.4. *Industrial requirements*

Considering the use case dedicated to car electronics disassembly, POLLINI (supported by POLIMI) identified the list of requirements of pertinence. This list is reported below:

- Gathering real-time (detailed) information about disassembly procedures in order to reduce both operation times and costs

- Gathering real-time (detailed) information on both new ELVs entering the process and 10-years old cars still circulating in order to create a specific database
- Gathering information about the remaining lifetime of valuable car parts (e.g. car electronics and batteries), by identifying the best EoL strategy to adopt
- Supporting operators involved in disassembly activities with technical datasheets reporting useful information about valuable car parts (e.g. physical location, embedded critical/valuable materials, indicative economic value, disassembly procedure, hazardousness) by exploiting the recycling knowledge in terms of materials (in)compatibility/recoverability associated with each disassembly level.
- Informing operators about the list of equipment/tools needed to implement a specific disassembly procedure
- Informing operators about the set of valuable car electronic components to be disassembled through pictures, symbols and hazardousness warnings
- Informing operators about health/safety rules to be adopted during disassembly operations (e.g. gloves, protective glasses, face masks)
- Informing operators about safety conditions to reintroduce disassembled parts in the second-hand market (legal requirements, technical standards, manufacturer requirements, etc.)
- Linking current information systems with the TREASURE platform
- Linking current disassembly to final treatment processes (e.g. with the hydrometallurgical pilot plant)

3.1.5. Use case specifics

About the use case dedicated to car electronics disassembly, POLIMI will implement within its I4.0Lab a dedicated semi-automated PCB disassembly cell. It will be constituted by a collaborative robot (cobot), a vision system and a set of equipment (e.g. end effectors, heating system) allowing the correct desoldering of components from PCBs. These PCBs will have been previously extracted from their metal/plastic cases through a manual process by POLLINI operators. TREASURE will support POLLINI's operators in two ways. Firstly, the cobot will support them during PCBs desoldering, in order to separate valuable electronic components (e.g. chips, memories, capacitors, etc.) from the main board. This activity will allow to increase the quality of recovered materials during the next recycling stages. Secondly, the TREASURE platform (specifically, its disassembly module) will support POLLINI's operators in the dismantling processes, providing proper instructions that the operator will be able to see in Virtual/Augmented Reality using the most suitable device. Instructions will also support operators in identifying the location of each electronic component within the car, by giving additional information about their market value, their materials content and the disassembly procedure to follow. The instructions will be also communicated to the collaborative robot located into the semi-automated line, which will support the worker in performing specific operations.

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Figure 6 – The DIS use case description table

Objective:	Owner & contributors:	Expected impacts:
• Semi-automated car electronics disassembly	• POLIMI • POLLINI • TXT • MARAS • SEAT • EUROLCDS	• Increase awareness • Improve performances • Provide information • Share knowledge

Industrial requirements:	Use case specifics:
• Gathering real-time (detailed) information about disassembly procedures in order to reduce both operation times and costs • Gathering real-time (detailed) information on both new ELVs entering the process and 10-years old cars still circulating in order to create a specific database • Gathering information about the remaining lifetime of valuable car parts (e.g. car electronics and batteries), by identifying the best EoL strategy to adopt • Supporting operators involved in disassembly activities with technical datasheets reporting useful information about valuable car parts (e.g. physical location, embedded critical/valuable materials, indicative economic value, disassembly procedure, hazardousness) by exploiting the recycling knowledge in terms of materials (in)compatibility/recoverability associated with each disassembly level. • Informing operators about the list of equipment/tools needed to implement a specific disassembly procedure • Informing operators about the set of valuable car electronic components to be disassembled through pictures, symbols and hazardousness warnings • Informing operators about health/safety rules to be adopted during disassembly operations (e.g. gloves, protective glasses, face masks) • Informing operators about safety conditions to reintroduce disassembled parts in the second-hand market (legal requirements, technical standards, manufacturer requirements, etc.) • Linking current information systems with the TREASURE platform • Linking current disassembly to final treatment processes (e.g. with the hydrometallurgical pilot plant)	• Manual extraction of PCBs from cases • Semi-automated PCB disassembly • Platform-based operations monitoring
TREASURE platform integration boundaries: • Xxx	TREASURE platform integration goals: • Xxx

*RED = described in D1.2

3.2. Car electronics recycling processes (REC use case)

3.2.1. Objective

The second use case refers to car electronics recycling processes. Within TREASURE, PCBs already disassembled by the DIS use case (see Figure 7 below and section 3.1 for details) will be recycled by application of a (bio-) hydrometallurgical processing pilot plant. In addition, In-Mold/Structural Electronics (IMSE) samples (e.g. printed graphics, thermoformed polycarbonate, encapsulated sensors) supplied by TNO and LCDs samples (e.g. ITO glass, PCBs, Cu connectors) supplied by EUROLCDs will be recycled in the same hydrometallurgical pilot plant in order to check for the reuse of materials in automotive applications. Together with the hydrometallurgical recovery of materials, a recyclability assessment will be executed through MARAS's recycling simulation models for both the PCB's and IMSE samples. Specifics about the materials recycling process adopted in TREASURE will be given in WP5 deliverables.

Figure 7 – Links between the DIS and REC use cases

AS-IS scenario

Like what already described for the current state of car electronics disassembly, also in terms of car electronics recycling processes there are similar issues. Given the aforementioned lacks in terms of car electronics disassembly, these components are left within the car wreck, and will partially end up into the incorrect recycled flows produced by physical processing. Due to the thermodynamic incompatibility of the materials of interest (minor /critical elements) in subsequent final treatment/recovery processes, as clearly reflected by the Metal Wheel (Reuter et al., 2013; Verhoef et al., 2004), these metals will end mostly in powders, ashes/flue dusts and slags of metallurgical processes related to base metals. Hence, the AS-IS status of recycling is still focused on the traditional concept of recycling by the application of shredding of the entire (mix) of products, followed by the final treatment of the produced recycled fractions in order to recover the metals/materials from it. It was proven by work on mobile phone recycling (e.g. Fairphone[3]), which has a very strong analogy with electronics in car design, that modular recycling in which selected disassembly of components as defined by modular design is followed by most suitable metallurgical processing infrastructures, will lead to higher recycling rates and lower losses of minor/critical elements (Ballester et al., 2017; Reuter et al., 2018).

AS-IS Challenges

- Absence of a European/national regulation on car electronics EoL management
- General perspective of car electronics EoL management as anti-economic procedure
- Relevant depletion of valuable/critical resources embedded in car electronics
- Relevant economic loss for the entire automotive value chain
- Low circularity of the automotive value chain in terms of critical materials recovery

3.2.2. Owners & contributors

- UNIVAQ (university) will implement a hydrometallurgical process
- UNIZAR (university) will study the thermodynamic rarity of materials embedded in car electronics
- ILSSA (car dismantler/shredder) will assess the UNIVAQ's solution and discuss about its integration with current processes
- SEAT (carmaker) will support ILSSA by sharing data on its car models and related components & materials
- TXT (ICT consultant) will support both UNIVAQ and ILSSA by implementing a dedicated module in the TREASURE platform
- MARAS (sustainability consultant) will support UNIVAQ, UNIZAR, ILSSA, SEAT and TXT by sharing knowledge and recycling/recovery data coming from its simulation models
- EUROLCDS (LCD manufacturer) will support UNIVAQ by supplying both PCBs to be recycled and related information (e.g. material contents, CAD files, etc.)

The scientific responsibility of the two use cases on car electronics recycling processes will be in the hands of UNIVAQ (REC scientific leader). The technical responsibility will be in the hands of ILSSA (REC leader).

3.2.3. Expected impact (TO-BE scenario)

One of the main intents of TREASURE is trying to increase the recovery rate of precious metals embedded into car electronics, without compromising on the recovery of the carrier metals and other materials. To this aim, the REC use case will be focusing on the recovery of critical and precious metals embedded in car electronics components. Within TREASURE, it is possible to assess the car electronics recycling issues from two perspectives, like the academic and industrial one. From an academic view, UNIVAQ will reconfigure its mobile pilot plant in order to treat car electronics components and recover critical and precious metals from them (see Table 6). From an industrial perspective, ILSSA will check the chance to integrate the UNIVAQ's

[3] Fairphone, https://www.fairphone.com/en/2017/08/08/examining-the-environmental-footprint-of-electronics-recycling

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003587

pilot plant with its current recycling process in order to increase the circularity level of the whole value chain. This way, there could be a direct comparison and quantification in terms of circularity performances (e.g. by exploiting WP2 and WP3 results – see Table 5). The comparison of the full recycling flowsheet will be supported by specific contributions from MARAS's recycling simulation models. Within the REC use case, the adoption of these simulation models will allow to compare the hydrometallurgical pilot with existing processing infrastructures, by enhancing the understanding of what must be considered within the use case (e.g. not focusing just on the recovery of desired elements/materials, but considering the creation of residues). Finally, UNIVAQ will be supported by a specific module of the TREASURE platform (dedicated to ELV recycling), the "Recyclability module" (see Table 6) providing information on the recycling/recovery rates of car raw materials/elements/compounds (including losses and emissions) and containing indications of best recycling routes and processes for optimum recovery. Specifically, the recycling assessment of the disassembled car electronics components will be done by MARAS. Subsequently, the assessment/optimisation of recycling of critical/minor elements (as well as all other carrier metals/materials included) of flexible electronics as performed in the pilot plant will be done by MARAS, that will also assess the recycling performance based on existing recycling infrastructures by application of the recycling models/modules. UNIVAQ will recover and optimize the recovery of critical materials in its pilot plant. Finally, the comparison of new flexible designs with conventional designs will be carried out (as well as the performance of the UNIVAQ process compared to existing metallurgical processes) by TNO, UNIVAQ, EUROLCDs and MARAS.

Table 5 – List of applied results from previous WPs & Tasks in the REC use case

Applied results from other WPs/Tasks	WP	Task	Task Leader
Sustainability & circularity assessment methods and KPIs	WP2	T2.1, T2.2	SUPSI
Recyclability analysis, guidelines & integration with CE indexes	WP3	T3.3, T3.4	MARAS, UNIZAR
Simulation, lab-scale tests & optimized materials recovery procedures	WP5	T5.3, T5.4	UNIVAQ

Table 6 – List of reference modules and technologies applied in the REC use case

Reference TREASURE platform's module
Recyclability module
Reference technology/asset
UNIVAQ's hydrometallurgical pilot plant (ref. FENIX project)

3.2.4. Industrial requirements

Considering the use case dedicated to car electronics (bio)hydrometallurgical materials recovery, UNIVAQ (supported by EUROLCDS) identified the list of requirements of pertinence. This list is reported below:

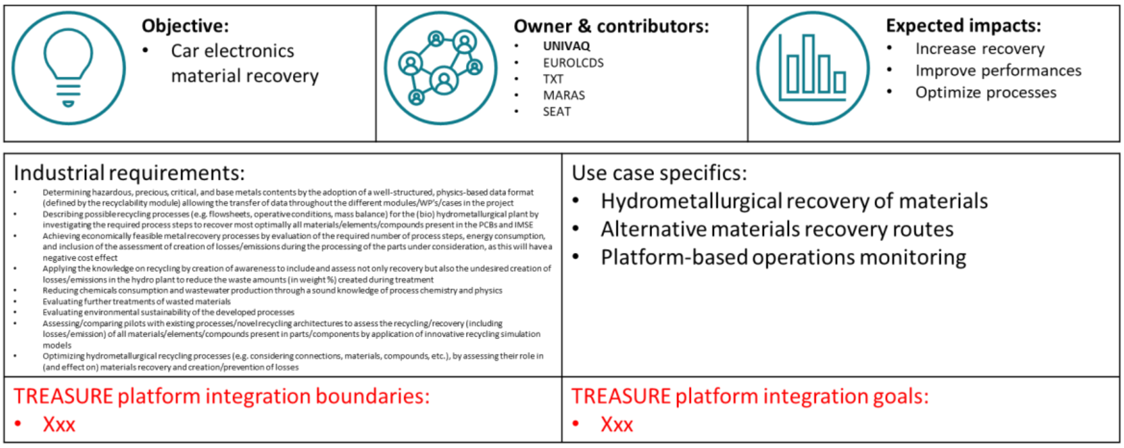
- Determining hazardous, precious, critical, and base metals contents by the adoption of a well-structured, physics-based data format (defined by the recyclability module) allowing the transfer of data throughout the different modules/WP's/cases in the project

- Describing possible recycling processes (e.g. flowsheets, operative conditions, mass balance) for the (bio) hydrometallurgical plant by investigating the required process steps to recover most optimally all materials/elements/compounds present in the PCBs and IMSE
- Achieving economically feasible metal recovery processes by evaluation of the required number of process steps, energy consumption, and inclusion of the assessment of creation of losses/emissions during the processing of the parts under consideration, as this will have a negative cost effect
- Applying the knowledge on recycling by creation of awareness to include and assess not only recovery but also the undesired creation of losses/emissions in the hydro plant to reduce the waste amounts (in weight %) created during treatment
- Reducing chemicals consumption and wastewater production through a sound knowledge of process chemistry and physics
- Evaluating further treatments of wasted materials
- Evaluating environmental sustainability of the developed processes
- Assessing/comparing pilots with existing processes/novel recycling architectures to assess the recycling/recovery (including losses/emission) of all materials/elements/compounds present in parts/components by application of innovative recycling simulation models
- Optimizing hydrometallurgical recycling processes (e.g. considering connections, materials, compounds, etc.), by assessing their role in (and effect on) materials recovery and creation/prevention of losses

3.2.5. Use case specifics

About the use case dedicated to car electronics recycling, UNIVAQ will reconfigure an already existing mobile pilot plant developed during a past H2020 project (www.fenix-project.eu). This pilot exploits a patented hydrometallurgical process in order to recover a set of base metals (e.g. copper) and precious metals (e.g. silver and gold) from obsolete PCBs. These PCBs (or their sub-components) will come either from EUROLCDS or POLIMI. In the first case, PCBs will be treated entirely (without grinding them). In the second case, PCBs will be previously disassembled within the POLIMI's pilot plant. This additional step is needed to check if the additional disassembly of electronic components from the main board will improve (or not) the recycling performance of subsequent processes. Once the POLIMI's results will be shared, ILSSA will study the viability of integrating a similar process in its recycling processes, by defining a specific business line for the recovery of PCBs.

Figure 8 – The REC use case description table



Objective:	Owner & contributors:	Expected impacts:
• Car electronics material recovery	• UNIVAQ • EUROLCDS • TXT • MARAS • SEAT	• Increase recovery • Improve performances • Optimize processes

Industrial requirements:	Use case specifics:
• Determining hazardous, precious, critical, and base metals contents by the adoption of a well-structured, physics-based data format (defined by the recyclability module) allowing the transfer of data throughout the different modules/WP's/cases in the project • Describing possible recycling processes (e.g. flowsheets, operative conditions, mass balance) for the (bio) hydrometallurgical plant by investigating the required process steps to recover most optimally all materials/elements/compounds present in the PCBs and IMSE • Achieving economically feasible metal recovery processes by evaluation of the required number of process steps, energy consumption, and inclusion of the assessment of creation of losses/emissions during the processing of the parts under consideration, as this will have a negative cost effect • Applying the knowledge on recycling by creation of awareness to include and assess not only recovery but also the undesired creation of losses/emissions in the hydro plant to reduce the waste amounts (in weight %) created during treatment • Reducing chemicals consumption and wastewater production through a sound knowledge of process chemistry and physics • Evaluating further treatments of wasted materials • Evaluating environmental sustainability of the developed processes • Assessing/comparing pilots with existing processes/novel recycling architectures to assess the recycling/recovery (including losses/emission) of all materials/elements/compounds present in parts/components by application of innovative recycling simulation models • Optimizing hydrometallurgical recycling processes (e.g. considering connections, materials, compounds, etc.), by assessing their role in (and effect on) materials recovery and creation/prevention of losses	• Hydrometallurgical recovery of materials • Alternative materials recovery routes • Platform-based operations monitoring
TREASURE platform integration boundaries: • Xxx	TREASURE platform integration goals: • Xxx

*RED = described in D1.2

3.3. In-mold/structural electronics prototyping processes (ECO use case)

3.3.1. Objective

The third use case refers to In-Mold/Structural Electronics (IMSE) prototyping processes. Within TREASURE, specific materials recovered from both car electronics (e.g. Cu and Ag) and selected plastic car parts (e.g. climate module and mid-console) by the REC use case (see Figure 9 below) will be reused in order to produce new in-mould/structural electronics. Specifics about the in-mould/structural electronics prototyping process adopted in TREASURE will be given in WP5 deliverables.

Figure 9 – Links between the DIS, REC and ECO use cases

AS-IS scenario

In-mould electronics is gaining interest in automotive to further integrate human-machine interfacing in panels within the dashboard, doors, chairs and car roof. Like conventional automotive electronics, in-mould electronics parts are not yet recovered. Moreover, the current means to manufacture in-mould electronics is to embed to a high degree all required functionalities, meaning sensors, actuators, lighting, and so on. This way of working does not facilitate dismantling of electronics to a degree that recycling of valuable components and materials is feasible.

AS-IS Challenges

- Like standard car electronics, IMSE is not recovered from ELVs

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- Current IMSE design/development/production processes do not consider circularity/sustainability requirements (e.g. disassemblability, recyclability)
- Increased demand from the automotive sector of more sustainable/circular products and components to be embedded into cars
- High level of secretness about materials embedded in IMSE
- Lack of information about LCA and LCC analyses on IMSE

3.3.2. Owners & contributors

- TNO (university) will implement an IMSE prototyping process
- UNIZAR (university) will study the thermodynamic rarity of materials embedded in car electronics
- WALTER (IMSE producer) will assess the TNO's solution and discuss about its adoption in new IMSE production processes
- SEAT (carmaker) will support TNO and WALTER by sharing data on its car models and related components & materials
- TXT (ICT consultant) will support both TNO and WALTER by implementing a dedicated module in the TREASURE platform
- MARAS (sustainability consultant) will support TNO, UNIZAR and TXT by sharing knowledge and recycling assessment data/figures and feedback to design improvement coming from its simulation model about alternative material recycling strategies (and related impacts)
- EUROLCDS (LCD manufacturer) will assess the TNO's solution and discuss about its adoption in new LCD production processes.

The scientific responsibility of the use case on IMSE prototyping processes will be in the hands of TNO (ECO scientific leader). The technical responsibility will be in the hands of WALTER (ECO leader).

3.3.3. Expected impact (TO-BE scenario)

Within TREASURE, the approach to create IMSE will be re-evaluated and improved where possible. To determine exactly the most environmentally impactful materials and processes, a Life Cycle Assessment (LCA) with End-of-Life (EoL) assessment is necessary. On forehand one may anticipate that the power consumption, the bulk plastics and the printed metals are the most impactful parts, but more details are required in order to know what parts we must prioritise. Nevertheless, in TREASURE the focus lies on adapting the design of IMSE to facilitate dismantling of such parts (see Table 7). If successful, it should be possible to directly access the Ag, allowing metallurgic recovery of this precious metal. Recycling of the plastic is considered quite challenging, as realistic re-use requires a low degree of contaminations. It is the aim to re-design IMSE parts such that the bulk plastic used, which is the backside injection moulded polycarbonate resin, is suitable for reuse. TNO will conduct the necessary experiments. Furthermore, TNO and WALTER will work together in creating an IMSE device in the third year of the project that contains some, if not all, of the found solutions. TNO will make use of the existing roll-to-roll line for flexible electronics, as established in the EU InScope project, for the development of the functional part of the device (see Table 8). Together with WALTER, SEAT and EUROLCDS a set of IMSE automotive applications will be chosen (e.g. climate control unit or middle console). MARAS will assess the recycling by application of the recycling models (e.g. by exploiting WP2 and WP3 results – see Table7), at the same time providing feedback on Design for Recycling based on pinpointing the options for improvement in design/material connections and usage from a recycling processing perspective (guaranteeing that the recycling is assessed and design for recycling suggestions are derived from a product centric, industry-based perspective).

Table 7 – List of applied results from previous WPs & Tasks in the ECO use case

Applied results from other WPs/Tasks	WP	Task	Task Leader
Sustainability & circularity assessment methods and KPIs	WP2	T2.1, T2.2	SUPSI
Eco-design analysis, guidelines & integration with CE indexes	WP3	T3.4	UNIZAR
Simulation, lab-scale tests & optimized IMSE prototyping procedures	WP5	T5.5, T5.6	TNO

This use case will leverage on a proper module of the TREASURE Platform, the “Eco-design module”, aimed at facilitating the “design for dismantling” approach, providing information on hardware components, valuable recommendations for the design phase based on KPI’s as derived from the disassembly and recycling module.

Table 8 – List of reference modules and technologies applied in the ECO use case

Reference TREASURE platform’s module
Eco-design module
Reference technology/asset
TNO’s roll-to-roll line for flexible electronics (ref. InScope project)

3.3.4. Industrial requirements

Considering the use case dedicated to secondary materials-based in-mould/structural electronics prototyping processes, WALTER (supported by TNO and EUROLCDS) identified the list of requirements of pertinence. This list is reported below:

- Identifying the list of materials recovered from car electronics that could be re-used in IMSE applications
- Checking the quality (e.g. transparency) of recovered plastics (e.g. polycarbonate)
- Checking the quality (e.g. conductivity) of recovered metals (e.g. Ag)
- Reusing plastics to produce green layers/pellets for IMSE applications

3.3.5. Use case specifics

About the use case dedicated to in-mould/structural electronics, TNO will reconfigure an already existing pilot plant developed during a past H2020 project (InScope). This roll-to-roll pilot plant is capable of printing graphic and conductive inks on flexible foils, after which Surface-Mount Device (SMD) components can be bonded with high precision. This will enable the development of the functional foil that is used within IMSE parts. Together with WALTER and EUROLCDS, a dedicated demonstrator will be made in WP6, based on a conventional part (e.g. climate control unit or middle console). To this end, conventional parts will be supplied by SEAT and dismantled by ILSSA. After these steps, materials/electronics that are re-obtained and may become suitable for reuse will be identified. The LCA and EoL for the conventional part may serve as a comparison to the one created for the IMSE part, allowing a more in-depth view of the improvements to the environmental impact enabled by this KET.

Figure 10 – The ECO use case description table

Objective:	Owner & contributors:	Expected impacts:
• IMSE eco-design	• TNO • WALTER • TXT • MARAS • SEAT • EUROLCDS	• Improve processes • Facilitate dismantling • Reduce env. impacts

Industrial requirements:	Use case specifics:
• Identifying the list of materials recovered from car electronics that could be re-used in IMSE applications • Checking the quality (e.g. transparency) of recovered plastics (e.g. polycarbonate) • Checking the quality (e.g. conductivity) of recovered metals (e.g. Ag) • Reusing plastics to produce green layers/pellets for IMSE applications	• Roll-to-roll production process • Focus on green IMSE applications • LCA comparison of traditional vs IMSE production processes • Platform-supported eco-design of IMSE
TREASURE platform integration boundaries: • Xxx	TREASURE platform integration goals: • Xxx

*RED = described in D1.2

4. Conclusions & next steps

The present deliverable (D1.3) documents the early results from the discussion with the use cases that are going to adopt the TREASURE solutions. The document has been developed to define an early logical picture of the industrial use cases, identifying the preliminary requirements to be used as input by WP5 and WP6 activities.

To drives these outcomes, a preliminary use case analysis has been performed, together with Task 1.2, defining the platform's requirements and functionalities that are supposed to enhance the transition towards the TO-BE status (that are documented in D1.2). An additional (more detailed) use case analysis will follow at M18.

The next steps will mainly flow into WP5 and WP6, addressing the lab-scaled development and optimization of the pilots and their validation & demonstration together with the TREASURE industrial partners. The activities will be carries out strongly collaborating with the other Work Packages, mainly WP5 for testing activities, and WP6 for the final validation of the TREASURE pilots.

5. Abbreviations

BoL	Beginning of Life
CCI	Circular Car Initiative
CE	Circular Economy
ELV	End-of-Life Vehicle
EoL	End of Life
I4.0	Industry 4.0
IMSE	In-Mold/Structural Electronics
ITO	Indium Tin Oxide
KET	Key Enabling Technology
LCA	Life Cycle Assessment
LCD	Liquid Crystal Display
PCB	Printed Circuit Board
PET	PolyEthylene Terephthalate
SMD	Surface-Mounted Device

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