D8.2: Exploitation plan (final version) and agreement

31/05/2024 (M36)

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Contributors: all other partners

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Technical References

Project Acronym	TREASURE
Project Title	leading the TRansition of the European Automotive SUpply chain towards a circulaR future
Project Coordinator	POLITECNICO DI MILANO (POLIMI)
Project Duration	36 months as of 1 June 2021

Deliverable No.	D8.2
Dissemination level [1]	PU
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Task	T8.2
Lead beneficiary	UNIVAQ
Contributing beneficiary(ies)	POLIMI, TXT
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Document history		
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V1.1	17/04/2024	UNIVAQ, POLIMI
VF	31/05/2024	UNIVAQ, POLIMI

DISCLAIMER OF WARRANTIES

[1]PU= Public
PP= Restricted to other programme participants (including the Commission Services)
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)

EXECUTIVE SUMMARY

The main aim of the TREASURE project is to develop new business models and industrial strategies for new supply chains in the automotive sector to enable value-added technologies and services. Through a set of success stories from the application of circular economy (CE) principles in the automotive sectors by involving all the stakeholders, TREASURE wants to demonstrate the real benefits of its adoption in practice. In addition, Key Exploitable Results (KERs) will be integrated within the selected processes to adopt the circular economy in the automotive sector for the recovery of precious, critical, and base metals.

Deliverable 8.2 focuses on finalizing the exploitation plan structure using, as a baseline, the initial exploitation plan presented in D8.1. To this aim, tangible and intangible results will be assessed in terms of:

a. Final definition of the TREASURE exploitation strategy;
b. Identification of the TREASURE KERs;
c. Definition of individual exploitation plans.

TABLE OF CONTENTS

1. Introduction

This chapter introduces the document containing its purpose and scope, the relation with other work packages and, finally, the document structure.

1.1. Purpose and scope

This document is the second (and final) release of the Exploitation Plan delivered at the end of the TREASURE project (M36). A previous version has been produced at M18. This version provides the description of the final exploitation preparation phase paving the way for the actual execution of the plan here defined. The document has been completely revised in respect to M18 version to convey a different message putting in evidence more the results and the adoption of them rather than the work done.

1.2. Relation to other TREASURE WPs

This deliverable is connected by design to all the activities in the project. In WP8 there is a close relationship with scientific and industrial Dissemination, communication, and clustering activities (WP7). As a matter of fact, the dissemination paves the way to exploitation activity being part of the same process aiming at letting other know about project activities and results, getting feedback from the markets to better focus fostering the use of the project results among the stakeholder communities and better structure and focus exploitation activities.

1.3. Document structure

Here below is provided the structure of the document:

- Chapter 2 describes the exploitable results. Such exploitable assets have been grouped into different packages depending on the scope that they will play into the overall exploitation framework. For each result is specified the owners, the exploitation channel, if it is necessary to acquire license to use it. For public results it is proposed Creative Commons (CC) to solve problem of licensing and Trademark.
- Chapter 3 (Individual Exploitation strategy) reports on individual exploitation actions, done by single partners of the consortium. The individual exploitation defines the partners' motivation in taking an active role in exploitation initiative. The Individual Exploitation describe the process by which each project partner takes advantages based on the foreground produced in the project. As part of the exploitation planning, each TREASURE partner has elaborated on the potential impact of the project and the commercial/societal value the outcomes will have in its company strategy.

The document ends with chapter 7 providing conclusions and future plans.

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2. TREASURE Key Exploitable Results

2.1. Introduction

This chapter describes the exploitation, focusing on what it will be exploited. Previous versions of the document use a bottom-up approach describing all results of the project and then describes the possible packages. This version, being the last one, uses a top-down approach by which the KERs are presented like in a catalogue, from the most complex ones to the fine granularity.

In the next subchapters, the envisioned KERs are described as comprising:

- TREASURE methodological package (Consultancy & Training)
- TREASURE digital package
- TREASURE industrial package
- TREASURE standardization package

An overview of the TREASURE exploitation hierarchy is presented below:

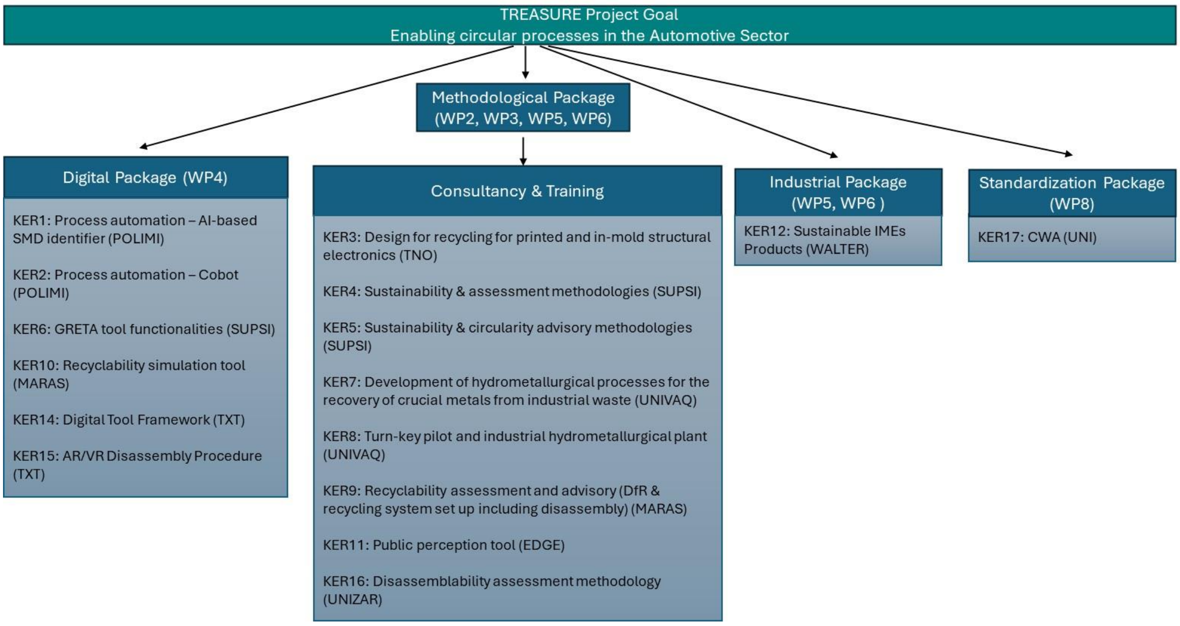

Figure 1. TREASURE KERs' hierarchy.

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2.2. Methodological Package

The methodological package (MP) consists of a set of tools and methodologies designed to support different players inside automotive industry to perceive, understand and decide on the CE adoption inside their specific domain. MP may help automotive industry to re-design company process and make company itself a new service provider inside the original product field. The MP is addressing the TREASURE arguments. The MP aim is to let the company analyse the CE domain and concept, analyse the CE potentialities in its own environment and instantiate, run, and accomplish the CE project. Sub-goals of the MP are about the development of CE skills and to identify effective and innovative strategies to deal with organizational renewal.

Generally speaking, "*Consultants*" are experts at helping organization manage the change and complexities inherent with CE adoption and instantiation/evolution. Main targets for the MP are decision making people: Manufacturing Enterprise top and middle management, Decision makers, Business Managers, Strategic consultants, Investors and Venture Capitalists, Policy makers, Supply Chain Managers, Production Managers, Life cycle Managers, Product chief Engineers, Service chief Managers.

The main drivers for this new approach and methodology are consultancy partners (EDGE and MARAS) and academic partners (POLIMI, SUPSI, TNO, UNIVAQ and UNIZAR) but even technical partners can be involved on a case-based approach and especially in the industry fields in which they have strong competences.

The MP is composed by the scientific results described in chapter and corresponding to 8 TREASURE KERs. At the same time, the MP could drive the adoption of the TREASURE Digital Package (supporting the implementation phase from an IT point of view) and the Industrial package (supporting the implementation phase from an operational point of view.

2.3. Digital Package

Through the Digital Package it is possible to implement the customer processes, method and tools designed using TREASURE Methodological Package. The Package provides assets for the actual instantiation phase starting from ideation to realisation of the CE. The overall architecture provides a unified view comprising all the technical results of the TREASURE project coming from WP1, WP2, WP3, WP4 and WP5 that were tested in WP6 through three testing activities. TREASURE refers to, possibly, widely used standards to promote both its integrability within operative contexts, as well as its capability to integrate and interoperate with other tools and services. Therefore, the design of the overall detailed architecture, as well as the identification of standards, technical solutions (e.g., protocols, APIs) has been performed considering the focus of each WPs.

2.4. Standardization Package

The standardization package regards the TREASURE CWA, that is a CEN/CENELEC Workshop Agreement (CWA) developed by a temporary group. A CEN Workshop Agreement (CWA) is a consensus-based document developed through a CEN Workshop, which is an open platform allowing direct participation from interested stakeholders. A CWA addresses immediate market needs and can be produced quickly. It is less formal than a European Standard and does not require formal national voting. Once consensus is achieved, the CWA is published to facilitate innovation and knowledge transfer.

2.5. Single Key-Exploitable Results

Among the whole duration of the project, TREASURE has generated several outcomes consisting of both IT and non-IT results. Example of *IT results* are software packages, services, platforms, and knowledge bases. At the same time *non-IT results* include methodologies, guidelines, approaches, best practices, lessons learned, plus associated business models. The purpose of this chapter is to provide the list of the single KER released by the project. The generation of project results has achieved following the project milestones as visible in the picture below.

Table 1. List of TREASURE KERs.

ID	KER title	Ref. WP	Ref. Del.	Owner / Contrib.	Nature	Package	IPR	KER Type
1	Process automation – AI-based SMD identifier	5	5.1, 5.2	POLIMI 100%	DEMO	DIG	Creative commons	PU
2	Process automation – Cobot	5	5.1, 5.2	POLIMI 100%	DEMO	DIG	Creative Commons	PU
3	Design for recycling for printed and in-mold structural electronics	5	5.5, 5.6	TNO 100%	DEMO	C&T	Intellectual property - WO2022220688	CO
4	Sustainability & circularity assessment methodology	2	2.1	SUPSI 100%	REP	C&T	Creative Commons	PU
5	Sustainability & circularity advisory methodology	2	2.2	SUPSI 100%	REP	C&T	Creative Commons	PU
6	GRETA tool functionalities	4	4.5	SUPSI 100%	DEMO	DIG	Closed source	CO
7	Development of hydrometallurgical processes for the recovery of crucial metals from industrial waste	5	5.3, 5.4	UNIVAQ 100%	REP	C&T	Intellectual property - WO2018/215967 WO2019/229632 + Patent pending	CO
8	Turn-key pilot & industrial hydrometallurgical plant	6	6.2	UNIVAQ 100%	DEMO	C&T	Intellectual property - WO2018/215967 WO2019/229632 + Patent pending	CO
9	Recyclability assessment and advisory (DfR & recycling system set up including disassembly)	3	3.3	MARAS 100%	REP	C&T	Closed source	CO

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10	Recyclability simulation tool	4	4.8	MARAS 100%	DEMO	DIG	Closed source	CO
11	Public perception tool	2	2.3	EDGE 100%	REP	C&T	Creative commons	PU
12	Sustainable IME products	6	6.3	WALTER 100%	DEMO	IND	Closed source	CO
13	Digital tool framework	WP4	4.7, 4.8, 4.9, 4.10	TXT 100%	Software	DIG	Closed source	CO
14	AR/VR disassembly procedure	WP4	D4.7, D4.8	TXT 100%	Software	DIG	Closed source	CO
15	Disassemblability assessment methodology	3	3.1	UNIZAR 100%	REP	C&T	Creative commons	PU
16	CWA	WP8	8.4, 8.5	UNI 100%	REP	STD	CEN CENLEC + Project partners	PU*

* The IP rights for CWAs are held by CEN and CENELEC, which are responsible for reproduction and distribution. All details regarding the intellectual property strategy of CWAs are contained in the CEN-CENELEC Guide 29

KER#1

Acronym and full title	Process automation – AI-based SMD identifier
Reference WP and Deliverable	WP5, D5.1 and D5.2
Contact person	Lorenzo Gandini
License of the result	Creative Commons (CC-BY-SA)
Ownership	POLIMI
Description	An algorithm was created to reconstruct and communicate the presence of SMD components to the cobot, and an optimal environment was created for the acquisition of PCB images. The algorithm was developed in Python with the OpenCV library, and it consists of a pipeline of several algorithms that extract the contours of all components of the board. The image is binarized through various CV algorithms, leaving only the contours of the components on the board highlighted so that they can be easily reached by a cobot.
Major characteristics	The algorithm, although not 100% accurate, is very simple and it allows a rapid execution to extract features from the image if the acquisition is performed in a controlled context. Although algorithms capable of identifying specific components present on boards exist in the literature, the presence of algorithms capable of extending cognitive capabilities to all components is scarce. This algorithm makes it possible to identify the presence of any component on the board by isolating components from the substrate, extending the applicability of this type of solution not only to the automotive electronics sector, but also to any electronic board. Although the system is relatively flexible, the critical points arise from the fact that it is necessary to manually calibrate certain parameters of the code to ensure the optimal operation with all PCBs. Furthermore, the algorithm does not present an optimal solution to the problem, but it was a first step in that direction paving the way for future developments.
Collaboration with other partners	N.A.
Availability of technical manual	N.A.
Availability of user manual	N.A.
Availability of source code	N.A.
Availability of binaries	N.A.

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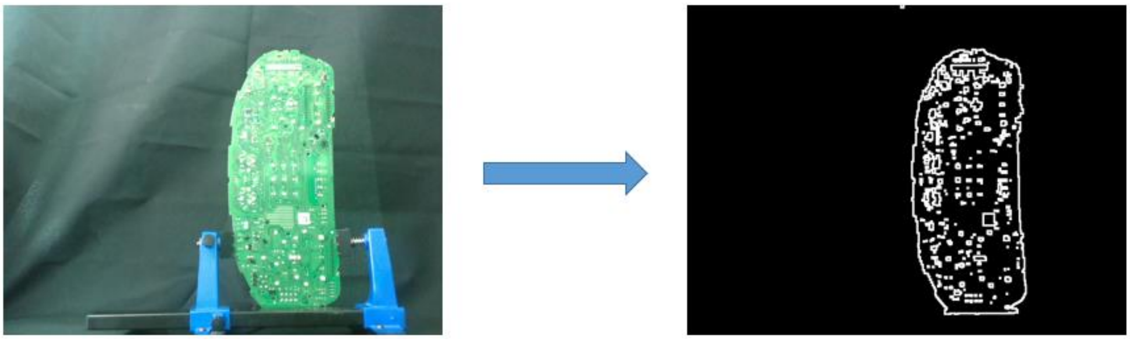
Screenshots of the KER
 KER#1 is displayed in D5.1 and D5.2

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KER#2

Acronym and full title	Process automation – Cobot
Reference WP and Deliverable	WP5, D5.1 and D5.2
Contact person	Lorenzo Gandini
License of the result	Creative Commons (CC-BY-SA)
Ownership	POLIMI
Description	In the context of the development of a disassembly process, POLIMI tried to make the most of the potential of Human Robotic Collaboration (HRC). The advantages of such collaboration emerge clearly in the literature although to date there are not many real-life applications of cobots to support operators. In the context of the TREASURE project, an attempt was made to further increase cooperation by allowing the operator to control and teach some basic operations to the cobot via a GUI.
Major characteristics	To support the operator during the disassembly of the electronic boards, a GUI was developed to speed up and simplify the interaction between the operator and the cobot. The application was developed in the ROS environment and the code was implemented in Python. The GUI allows the operator to teach new operations to the cobot, check them in simulation, save them and then execute them on call. A suitable simulation environment was developed in Rviz to allow the operator to check the learning procedures before executing them in the real environment.
Collaboration with other partners	POLLINI provided Printed Circuit Boards (PCB) and related materials.
Availability of technical manual	N.A.
Availability of user manual	N.A.
Availability of source code	N.A.
Availability of binaries	N.A.
Screenshots of the KER	

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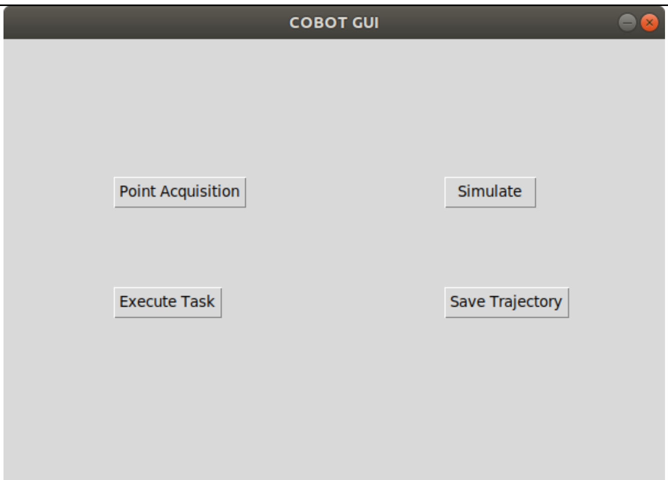

Screenshot of the Learning GUI

KER#2 is displayed in D5.1 and D5.2

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KER#3

Acronym and full title	Design for recycling for printed and in-mold structural electronics
Reference WP and Deliverable	WP5, D5.5 and D5.6
Contact person	Stephan Harkema
License of the result	Intellectual property - WO2022220688
Ownership	TNO
Description	The possibility to dismantle highly integrated in-mold structural electronic devices offers the potential to recover the plastics as well as the printed metal and SMD components, which could result in improved recycling rates, but could also provide alternative recycling routes that would otherwise be hampered by the presence of an encapsulation. Our expectation of a reduced overall environmental impact in a cradle-to-grave, or potentially in a cradle-to-cradle lifecycle analysis, comes from the potential end-of-life scenarios other than shredding and incinerating at economy of scale which sacrifices the plastics as an energy carrier or reductant in the metallurgic recovery process for the metals. To the best of our knowledge, our efforts to dismantle IME are novel and unique in the world at the time of writing. Designs-for-recycling that incorporate features that facilitate product disassembly and potentially improve recycling, may involve a balancing act of product reliability and improved sustainability. While reliability tests were performed in this study under the harsh conditions that are specified by the automotive industry. The devices we examined were found to stay structurally intact in test at Holst Centre. We believe that such design-for-recycling principles may lead to the possibility of repairable printed electronics in the future, thereby delivering on the promise of sustainable (printed) electronics. Recycling of plastics was performed before and after disassembly by TNO and combined with Ag recycling by UNIVAQ. Physical recycling of IME partners was performed by dissolution and uniquely leaves the polymer intact. Pure polycarbonates were obtained, for encapsulation and substrate separately if needed, indicating that pollutants were successfully removed. Graphic inks, other coatings and semiconductor components could be retrieved from the parts by dissolution of the plastics. Since filtering of Ag particles from the solvents may be insufficient, recovery of Ag via this route may not be optimal. Dismantling is essential to increase

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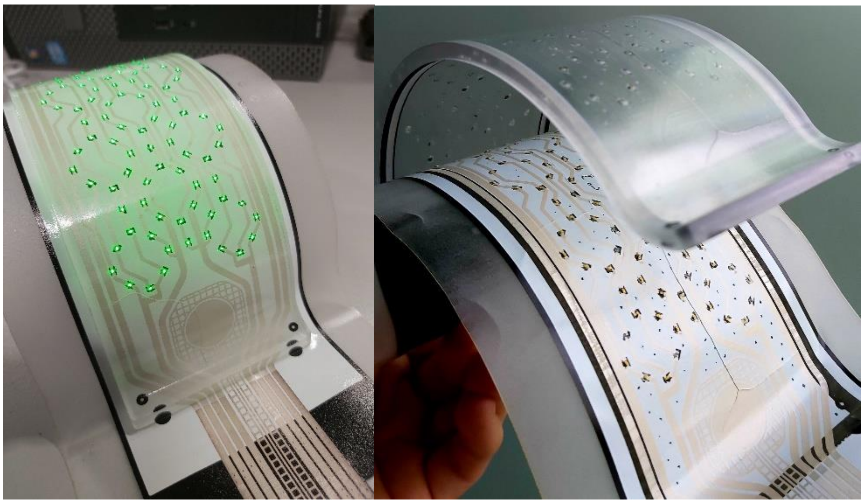
	the recovery rate of especially the metals, without sacrificing plastics unnecessarily.
Major characteristics	The key enabling results exploited by TNO concerns consultancy and training services on the topic of design-for-recycling for printed electronics in general, but in-mold structural electronics specifically.
Collaboration with other partners	In the framework of other EU projects, we continue to collaborate on the topic (e.g. in EU Unicorn and Circ-uits). TactoTek may be interested to bring our solutions for sustainable IME to the automotive industry. A first announcement has been made of our collaboration in Oct 2023 (TactoTek® and Holst Centre at TNO Partner to Advance In-Mold Structural Electronics (IMSE®) and IMSE Circularity).
Availability of technical manual	None. Approach was described in full in Journal of Cleaner Productions: DOI: 10.1016/j.jclepro.2024.141837
Availability of user manual	None.
Availability of source code	Not relevant.
Availability of binaries	None.

Screenshots of the KER



KER#3 is displayed in D5.5

KER#4

Acronym and full title	Sustainability & circularity Assessment methodology
Reference WP and Deliverable	WP2, D2.1
Contact person	Alessandro Fontana
License of the result	Creative commons
Ownership	SUPSI
Description	The Sustainability and Circularity Assessment methodology developed within TREASURE project, allows life cycle sustainability and circular assessment (LCS&CA) to be carried out in the different project use cases. The methodology is composed by: • A selection of environmental, economic, social, and circular assessment methodologies from the analysis of state-of-the-art that fit the adoption context. • A selection of LCS&CA indicators proposed by methodologies and their respective calculation formulas according to criteria such as quantifiability and data availability. • A selection of existing assessment methodologies and standards to aggregate and integrate the three areas of sustainability and the circularity to provide a holistic interpretation of the assessment results.
Major characteristics	The methodology makes a step forward in the field of LCS&CA by identifying the most widely accepted and validated methodologies and by selecting indicators, and aggregation/integration methods according to the project's target product, i.e., electronic components of car parts. Starting from the project pilot cases, it is possible to extend the methodology adoption to off-project use cases in the future. This approach has been designed to ease the understanding in both the selection of appropriate aggregation methods and the choice not to aggregate results. KER#4 laid the foundation for the development of the advisory methodology and of SUPSI sustainability assessment tool. The LCS&CA-based tool will help to automate the previously described process, enabling data acquisition, automatic assessment calculation, aggregation, and results presentation.
Collaboration with other partner	The use case partners and UNIZAR, MARAS and POLIMI have been involved in validating the effectiveness of the methodology and indicator selection approach, through questionnaires and direct interaction.
Availability of technical manual	N.A.

Availability of user manual	N.A.
Availability of source code	N.A.
Availability of binaries	N.A.
Screenshots of the KER N.A.	

KER#5

Acronym and full title	Sustainability & circularity Advisory methodology
Reference WP and Deliverable	WP2, D2.2
Contact person	Fontana Alessandro
License of the result	Creative commons
Ownership	SUPSI
Description	The Sustainability & Circularity Advisory methodology is a methodology able to support decision-making. The approach is specifically designed to facilitate decision-making processes related to disassembly, recycling, and eco-design of electronic components in the automotive industry. The main objective is to promote the implementation of more sustainable and circular practices by maximizing the extraction of materials from end-of-life components and reintegrating them into the production cycle through recycling. In addition, this methodology serves as a guiding framework to assist in the design of electronic components with improved sustainability and circularity characteristics, also facilitating future disassembly and recycling processes. The methodology underpins the Advisory tool, which is one of the functionalities of the TREASURE Platform, developed by TXT in WP4.
Major characteristics	The innovative aspect of the Sustainability & circularity Advisory methodology relies on the creation and formalization of an advisory framework that considers the connections among the three stages (disassembly, recycling, design) of the value chain, implementing both preventive and curative strategies. This kind of framework was still missing in the automotive field, with another innovative aspect that is the adoption of a feedback system across EoL and BoL actors that supports closing the loop through information sharing and

	improving the sustainability and circularity performance along the value chain. The advisory methodology offers an integrated vision embracing technical, sustainability, and circularity aspects, trying to integrate, in the functional development and assessment, i. the economic evaluations in terms of cost and revenues, ii. the environmental evaluations in terms of processes' impacts, iii. the circularity evaluation in terms of the recyclability and thermodynamic rarity calculation, iv. the social evaluations in terms of risks for the stakeholders to be safeguarded according to the social goal and scope of the project.
Collaborations with other partners	Pilots have been involved in order to identify when and how the sustainability advisory can provide support for design, disassembly and recycling phases, ensuring a higher level of economic, environmental, social, and circularity performance. In addition, sector decision rules extracted from them have been used to align the advisory tool with the industry's existing decision drivers. TXT and POLIMI have been involved in order to refine the overall decision-making flow. Another relevant support has been provided by external stakeholders through a survey developed by TXT to identify possible enhancement of the advisory methodology.
Availability of technical manual	N.A.
Availability of user manual	N.A.
Availability of source code	N.A.
Availability of binaries	N.A.
Screenshots of the KER N.A.	

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KER#6

Acronym and full title	GRETA tool functionalities
Reference WP and Deliverable	WP4
Contact person	Fontana Alessandro, Giuseppe Landolfi
License of the result	Closed source
Ownership	SUPSI
Description	GRETA is a web-based microservices application developed and operated by SUPSI for assessing sustainability and circularity in manufacturing. The tool offers diagnostic and advisory features, ranging from assessment in compliance with LCA, LCC, SLCA, and circular economy metrics, to advisory and decision support offered to users to compare alternative production scenarios or product configurations. Integration with production systems, provision of REST APIs functionalities and the possibility to export report in different formats streamlines the direct interaction with the users. GRETA can import processes modelled in OpenLCA and BOM data from standard files to shorten the time for product and process modelling. The platform is today intended to serve two user typologies: sustainability experts on one side and customers (usually from manufacturing companies, such as designers, technicians, and decision maker managers).
Major characteristics	Thanks to GRETA Sustainability Experts can create life cycle process models and define customization spaces for each modelled process, so to allow Customers to make specific customizations to products, machines, or processes. On the other side, Customers utilize GRETA to assess the sustainability performance of their products, machines, or processes and to identify possible improvements to implement.
Collaborations with other partners	SUPSI owns entirely the result of GRETA and its enhanced functionalities. In TREASURE, SUPSI collaborated with TXT for the integration of GRETA with the TREASURE platform.
Availability of technical manual	Not available (closed source)
Availability of user manual	Video-based tutorial for users
Availability of source code	Not available (closed source)
Availability of binaries	Not available (cloud-based application)
Screenshots of the KER	

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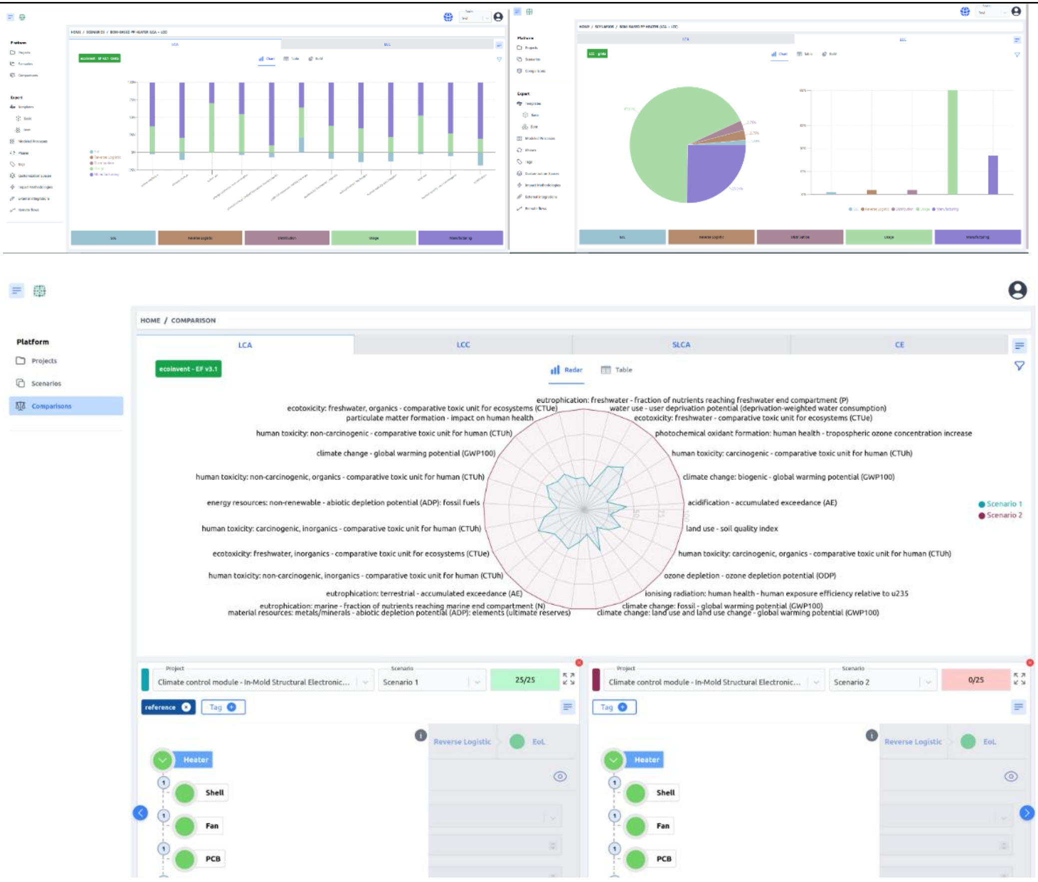

KER#6 is displayed in D4.10

KER#7

Acronym and full title	Development of hydrometallurgical processes for the recovery of crucial metals from industrial waste
Reference WP and Deliverable	WP5 (D5.3 and D5.4)
Contact person	Francesco Vegliò, Nicolò Maria Ippolito
License of the result	Background IP: the hydrometallurgical processes named Gold-REC 1 (International Publication number: WO2018/215967) and Gold-REC 2 (International Publication number: WO2019/229632) are patented at the European level. Foreground IP: the recycling of silver from IMSEs and materials with similar characteristics, as well as the recycling of indium from LCDs and materials with similar characteristics, are the subjects of a pending patent.
Ownership	UNIVAQ
Description	This KER includes developing hydrometallurgical processes for recycling industrial waste to recover valuable/crucial metals such as base, precious, and critical. Processes are investigated using a minimal-liquid-discharge (MLD) approach to decrease water consumption and reagent use. Furthermore, the value of each output process is investigated to establish a route for secondary products. The main consulting services offered are outlined below: • characterization of the metal fraction of the material provided by the customer to determine the content of the valuable metals; • estimation of the intrinsic economic value (IEV) of the material based on the metals content and their market quotation; • identification of the metals to be recovered from the material; • study of the hydrometallurgical process at laboratory scale to determine the operative conditions to maximize the extraction yields and to reduce the operative costs (counter-current leaching, reuse of water, wastewater treatment, MLD approach); • process analysis (mass and energy balances) and preliminary economic analysis; • test of the developed process at pilot scale by using the reconfigured hydrometallurgical pilot plant (TRL5); • process analysis and business plan (economic index such as ROI, PBT, GOP); • training for the use of the hydrometallurgical pilot plant for the personnel customers provided by qualified staff.

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Major characteristics	The consultancy service is mainly addressed to recycling companies. UNIVAQ can offer support for the development of hydrometallurgical recycling processes for any type of industrial waste. The added value of the following proposal is related to the advances that UNIVAQ achieved within the Treasure project on the **recycling of PCBs** from the automotive sector. Although UNIVAQ already owned two patents for the recycling of precious and base metals from PCBs, within the project, a preliminary disassembly operation that allows for increased metal extraction yields has been studied. Specifically, two hydrometallurgical routes have been identified: one for specific SMDs based on their precious metal content and status, and the second for the board with the residual SMDs. In addition, thanks to the reuse of water through a counter-current leaching process and the introduction of a section for wastewater treatment, the use of water has been significantly reduced. In the ambit of the project, UNIVAQ has acquired expertise in the recycling of other car components such as LCDs that are essentially used in the infotainment unit. In addition, also the recovery of silver from IMSEs has been developed. IMSEs is an emerging technology that in the next years could partially replace conventional printed circuit boards in the automotive sector. Hydrometallurgical processes according to a MLD approach aimed at **recovering indium from LCDs** and **silver from IMSEs** have been developed and patented. The recovery of silver plays a crucial role in the energy transition since there is a high demand, particularly for photovoltaic panels. The developed technology for the recycling of IMSEs can also be transferred to photovoltaic panels with accurate study on a laboratory scale for process optimization. The developed process of the recycling of silver makes it possible to recover valuable raw materials and re-enter them on the market, generating profits. Preliminary studies have been conducted in the project for the circularity of silver to be reused as a precursor for new ink. The developed hydrometallurgical process can ensure benefits not only from an economic point of view but also from environmental sustainability by adopting the MLD approach and chemical recycling.
Collaborations with other partners	The activity of TNO on the recycling of polycarbonate from IMEs. GENESINK (AB member) for the activity related to the circularity of silver to test the re-enter in the market of the silver recovered by the hydrometallurgical process.
Availability of technical manual	No
Availability of user manual	No
Availability of source code	No

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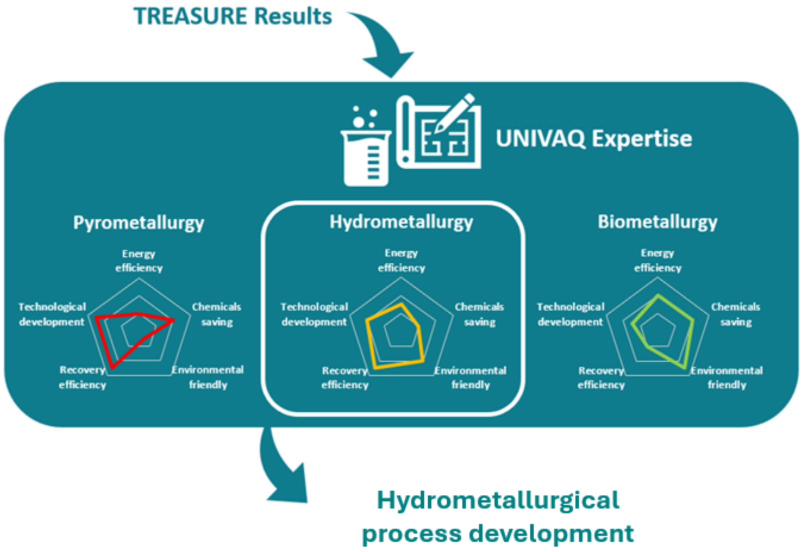
Availability of binaries	No
Screenshots of the KER	



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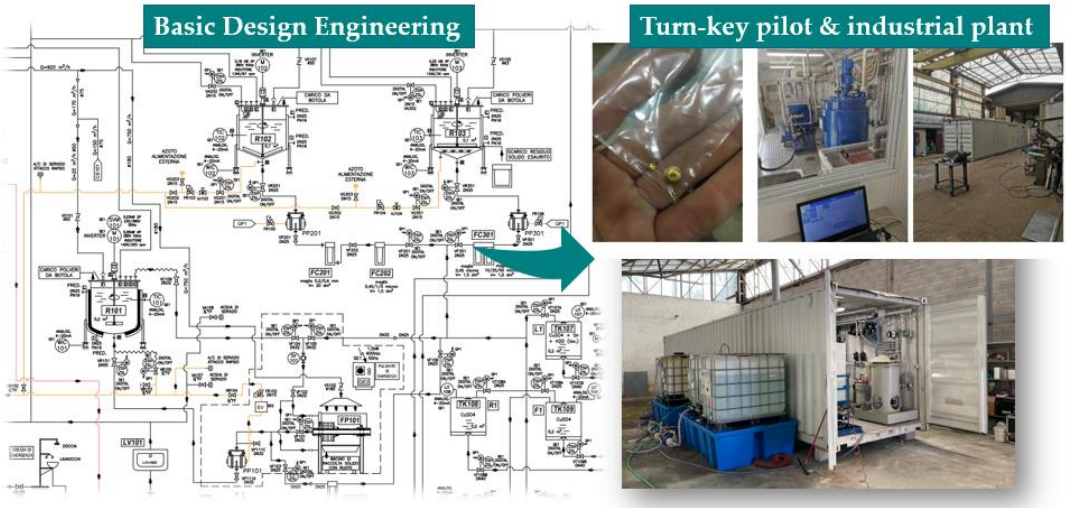
KER#8

Acronym and full title	**Turn-key pilot & industrial hydrometallurgical plant**
Reference WP and Deliverable	WP6 (D6.2)
Contact person	Francesco Vegliò, Nicolò Maria Ippolito
License of the result	The license of the results for the exploitation of the "turn-key pilot & and industrial hydrometallurgical plant" is closely related to the type of material under investigation for the development of the hydrometallurgical recycling process. Specifically for some kind of waste such as PCBs, LCDs, IMSEs, and materials with similar characteristics, the following licenses must be considered: • Background IP: the hydrometallurgical processes named Gold-REC 1 (International Publication number: WO2018/215967) and Gold-REC 2 (International Publication number: WO2019/229632) are patented at the European level. • Foreground IP: the recycling of silver from IMSEs and materials with similar characteristics, as well as the recycling of indium from LCDs and materials with similar characteristics, are the subjects of a pending patent. No specific licenses have been developed for plant protection.
Ownership	UNIVAQ
Description	Typically, this KER is generated through the consulting activities conducted with KER#7. Therefore, based on the achieved results in terms of hydrometallurgical process development, UNIVAQ supports the customer/recycling company in the building of a turn-key pilot & industrial hydrometallurgical plant. The building of the plant occurs according to the following steps: • market analysis to identify the plant capacity; • Basic Design Engineering (BDE) with the selection of the equipment and the production of piping & instrumentation diagrams (P&ID); • turn-key hydrometallurgical plant realization; • supporting the plant start-up activity.
Major characteristics	Numerous systems for recovering metals from different types of waste are presented in the literature. In addition to these data, it is also possible to find a relatively large number of patents and licenses for pyrometallurgical, hydrometallurgical, and bio-hydrometallurgical extraction processes. Among these methods, the present KER is focused on the realization of plants that exploit the hydrometallurgical route,

	which seems to be promising if developed by considering not only technical and economic aspects but also looking a comprehensive sustainability. Therefore, the strategy is to enhance hydrometallurgical processes, focusing on minimizing their disadvantages by implementing a MLD approach (minimization of wastewater production). Address the specific areas of environmental impact, cost-efficiency, and process sustainability. The outcome outlines a plan that incorporates innovative techniques and technologies to achieve these improvements. In addition, always a wastewater treatment section is included in the hydrometallurgical plant. More in detail, external partners cooperate with UNIVAQ to the realization of turn-key plants. External partner Smart Waste Engineering (SWE) supports UNIVAQ for the basic design engineering with dedicated software for P&ID and technical and safety manual preparation. BFC Sistemi S.r.l. (BFC), which operated for the reconfiguration of the TREASURE pilot plant, deals with the construction of the hydrometallurgical plants.
Collaborations with other partners	No
Availability of technical manual	Yes
Availability of user manual	Yes
Availability of source code	No
Availability of binaries	No
Screenshots of the KER	



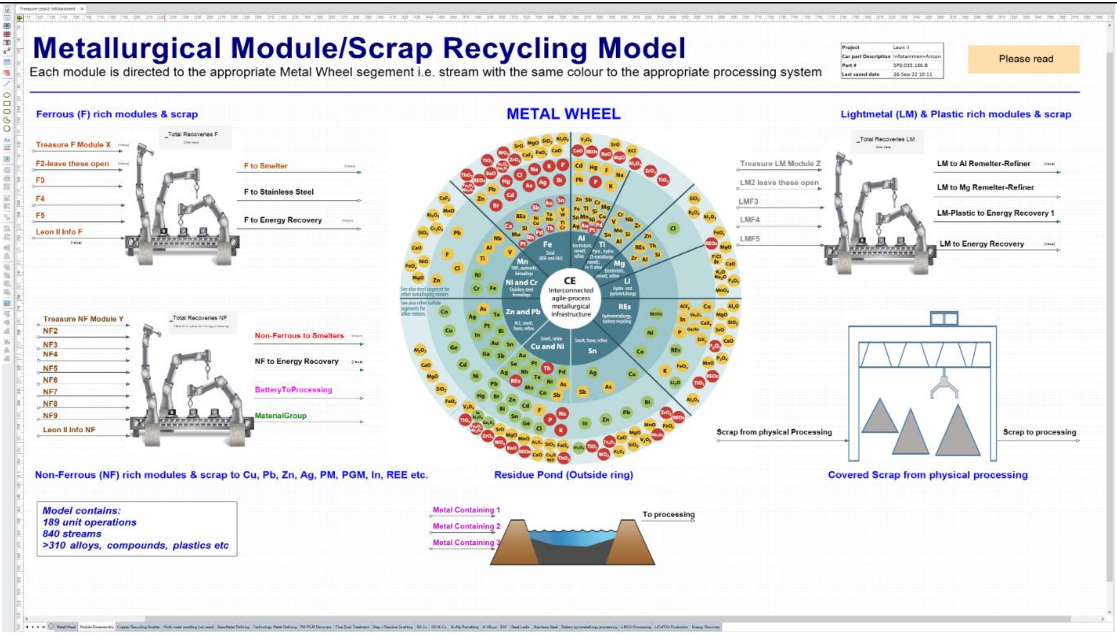
KER#9

Acronym and full title	Recyclability assessment and advisory (DfR and recycling system setup including disassembly)
Reference WP and Deliverable	WP3, D3.3
Contact person	Antoinette Van Schaik
License of the result	Closed source
Ownership	MARAS
Description	The "Recyclability Assessment and Advisory" consultancy/service integrates advanced physics-based simulation models with practical industry based know-how and expertise to assess and enhance the recyclability of products at their End-of-Life (EoL). This approach also allows for rigorous Design for Recycling (DfR) principles, which seek to maximize material recovery through effective product and system design. The advisory services is based on a comprehensive definition of the recycling system, which includes disassembly processes, shredding and sorting and BAT and innovative final treatment (metallurgical) processing infrastructures into advanced simulation tools which digitally twin the entire recycling system on a physics basis. This setup is crucial for understanding and optimizing the separation and recovery of materials from complex multi-material products. **Physics-based Simulation Models:** Developed over decades by MARAS B.V., these models simulate the disassembly, liberation, and sorting processes linked to the best available techniques in metallurgical and final treatment recycling processing. They are designed to quantify and improve resource efficiency on a full mass, energy and exergy balance basis for all materials/elements/compounds contained in products/parts by creating a digital twin of the recycling processing flowsheets. **Recycling System Design:** Using insights derived from simulation models, the system allows for configuration of most optimal recycling flowsheet architectures to balance disassembly with the most suitable and efficient recycling processing infrastructures uniquely defined for different design and recycling objectives. Linking this to disassembly advice and DfR this ensures that the design and composition of products are (as far as possible respecting the limits of functional requirements) aligned with metallurgical processing capabilities, enhancing resource recovery, and

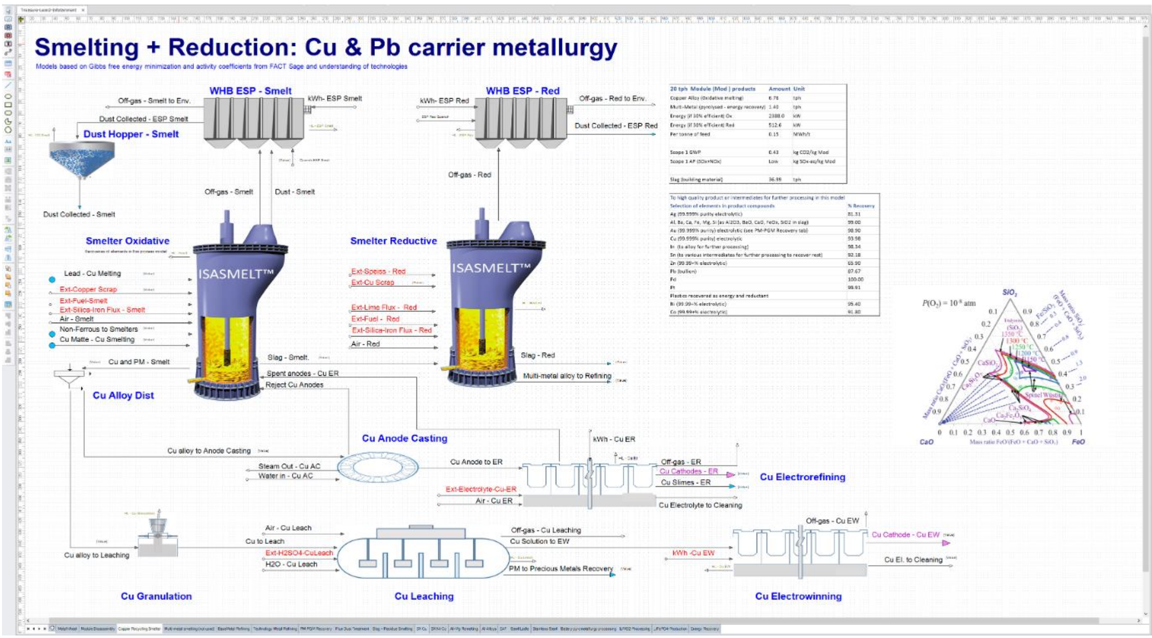
	ensuring the highest quality of recycling products to fulfil the true objective of Circular Economy **Consultancy and Advisory:** Expert advice is provided to optimize the recycling system based on the specific characteristics of the products and the industry standards. This includes recommendations on disassembly techniques and adjustments to the recycling process flowsheet based on the physical and chemical properties of the materials and recycling processes involved. End-of-Life (EoL) Phase Integration: The service includes designing recycling systems that are tailored to the EoL phase of products, incorporating considerations for modularity and ease of disassembly, which are essential for effective recycling. Life Cycle Assessment (LCA) Input: The models offer detailed insights into the exergy and energy flows during the recycling process, providing critical data that can be used for environmental impact assessments through LCA and can be linked to OpenLCA.
Major characteristics	This service provides a strategic framework for companies looking to assess and enhance the sustainability and circularity of their products by improving the recyclability at the end of their lifecycle. By utilizing state-of-the-art simulation tools and expert advisory, businesses can design products and recycling systems that not only meet regulatory standards but also reduce environmental impact and increase material recovery and quality. The approach is especially beneficial for industries involved in the recycling of complex products such as electronic devices and automotive parts, where precise material separation is crucial for sustainability. At the same time, industry at beginning of life, OEMs and equipment manufacturers can benefit from this expertise and advisory in view of recycling/circularity assessment of their product as well as to perform true recycling technology driven Design for Recycling based on quantified hot-spot identification of Design improvement options based on the unique recycling fingerprint of each individual design and design alternative in order to improve and prove innovation and development towards S&C. Recycling rates of the car parts for the total car parts/products as well as for all materials/compounds/elements composing the car parts are calculated on this basis for true circularity, i.e. recycling into materials with a quality that can be applied in the same product (closed loop CE). The assessment of the recycling system is performed by the application of recycling flowsheet simulation modelling and provides the following results and knowledge, which provide the basis for this KER to be exploited for consultancy and advisory.

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

	KPI's on recycling/recovery for whole parts/product as well as for individual elements/materials - Total recycling rate (% and mass), which can also be expressed in terms of kW via the enthalpy of the complex solutions - Individual material recycling rate of all materials/elements/compounds included in the car part (% and mass) - Energy recovery in MWh/t of feed or per car part - Exergy in kW of all flows as the entropy of the complex mixtures can also be quantified The expert knowledge and process simulation model provide the basis for exploitation by providing consultancy, calculations and advise for the EoL phase of products as well as for DfR and optimal design of recycling systems (including balancing disassembly with recycling processing).
Collaborations with other partners	ER11 is solely developed by MARAS, but works as an input to the joint ER called TREASURE platform, described in D8.7, specifically for the REC and ECO modules.
Availability of technical manual	The consultancy and advisory is carried out by MARAS and based on MARAS detailed and extensive industrial and scientific expertise. No technical manual is available; however, MARAS is well experienced in communication with clients on approaches, tools, data requirements and results and their application. The methodologies behind the work of MARAS (as developed within MARAS) are widely described and presented in many peer reviewed as well as industry focussed journals and books.'
Availability of user manual	See previous point
Availability of source code	The source code of the models is developed and owned by MARAS and not made available being IP of MARAS
Availability of binaries	see above
Screenshots of the KER	



Visual summary of the simulation-based approach used to determine the recycling rate of the different car parts : Overview of simulation model (Feeds flowsheet) showing that in the process model, the "Feeds" sheet is of importance as it shows in which metallurgical processing infrastructure (according to the segments of the Metal Wheel in the middle) the car parts and possible disassembled sub-parts are processed in linked tabs (full processing infrastructures) that represent the different segments of the Metal Wheel/recycling processing flowsheets



One of the processing infrastructures of the wide range of routes as included in the recycling process simulation models : Cu processing route' – Oxidative smelter (Cu Isasmelt™)), reduction of Pb bullion (Pb Isasmelt™ Reductive smelter) and Cu refining. Note that to maximize the recovery metals e.g. from slags and flue dusts, these are processed in the other tabs of process model (see each tab label for detail), this means the Cu processing route embraces in fact many more tabs than simply only the figure above (see Figure above for overview).

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

KER#10

Acronym and full title	Recyclability simulation tool
Reference WP and Deliverable	WP4
Contact person	Antoinette Van Schaik
License of the result	Closed source
Ownership	MARAS
Description	As the Recycling Simulation Tool is the basis for the Recycling Module as well as for the recycling related parts of the ECO module within the Treasure Digital Toolbox, the knowledge base of this KER, is similar to the knowledge base for the KER 11. Computer-based modelling and process simulation tools of the recycling technology and system performance of products have been developed and applied by Van Schaik and Reuter (MARAS) over many years for the recycling of complex products to understand and capture the factors that improve design for resource and exergy efficiency. These models also include expert rule-based modelling of the relation between design and liberation behaviour, particulate quality, physics of sorting efficiency, recyclate quality, distribution of materials/compounds over all produced recyclates, and recycling products and metallurgical process efficiency as a function of design and recyclate composition (Van Schaik and Reuter, 2007). This implies that sophisticated tools exist within MARAS that enable the evaluation and optimisation of resource recovery in metal and material processing systems. Innovative recycling process simulation models have been advanced, extended and further developed by MARAS within the TREASURE project based on existing know-how and developed simulation model-based recycling assessment methodology as referenced above. The recycling simulation models are developed and applied to assess the full circularity of the end-of-life stage of car (electronic) parts and products. The development especially was focusing not so much further developing the flowsheet but being able to deal with the large number of different compounds and associated elements in the various process streams of the complete flowsheet. These approaches and tools provide unique know-how and results on recycling and provide the basis for the Recycling Module as well as for the ECO module as part of the TREASURE platform tool. The recycling simulation models, data and results provide the basis for the REC module and advisory and DfR part of the ECO module and advisory. Intrinsically linking EoL LCA in recycling

	simulation models allows for the link of this detail to LCA tools (in platform and existing tools) in future (not yet part of this KER due to the limit in current integration of the detail of the Recycling Simulation Models in the platform, which is now only based on static data interaction, but can be further explored in future to be captured by Neural Nets, surrogate functions etc. as we have applied already in the past in other work). Specifically, also a focus was given to further develop the idea that environmental assessment should focus more on the physiochemical aspects of all parts of the system. The process simulation models have been developed in the industrial software platform HSC Chemistry Sim® 10 (www.metso.com), providing a professional and industrial platform for process simulation tools and recycling as well as environmental impact calculations. This simulation-based methodology has been applied within the TREASURE project for the assessment of the recyclability of car product designs, car part recycling performance, EoL system assessment to truly quantify and support CE in the Eol phase of products. The results/models have been equally applied for any other (complex) product recycling assessment, flowsheet development, DfR and disassembly assessment. The models also have been used to assess the recyclability of IME and define/asses the most optimal flowsheet architectures, as well as to benchmark developed bio-hydrometallurgical plant design against existing options.
Major characteristics	The tool covers the full recycling and metallurgical processing flowsheets for all best available techniques for the economically viable multi-metal metallurgical and final treatment recycling processing which exist in industry. These different recycling infrastructures are presented by the segments of the Metal Wheel (in the middle). Detailed flowsheets for each of the processing routes are covered in full process detail in the recycling system model, which provides a digital twin of (metallurgical) recycling industry and have been further developed and applied within the TREASURE project to assess the recycling of various car (electronic) parts as well as IME and assess and optimise their disassembly and balance this with recycling infrastructures. The flowsheet model used and advanced for this simulation-based approach is based on industrial economically viable processing. It contains all unit operation in the various processing routes (in this stage 190-unit operations) and ca. 310 materials and compounds as can be present in the car parts and produced by the flowsheet as well as over 840 streams for all phases including metals, molten flows, aqueous, dust, slimes, slags, calcine etc.

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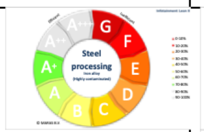
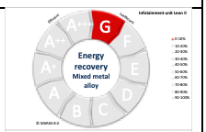
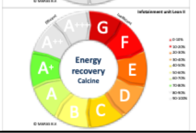
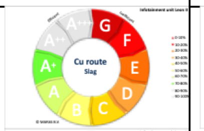
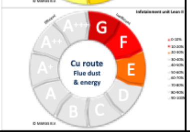
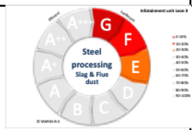
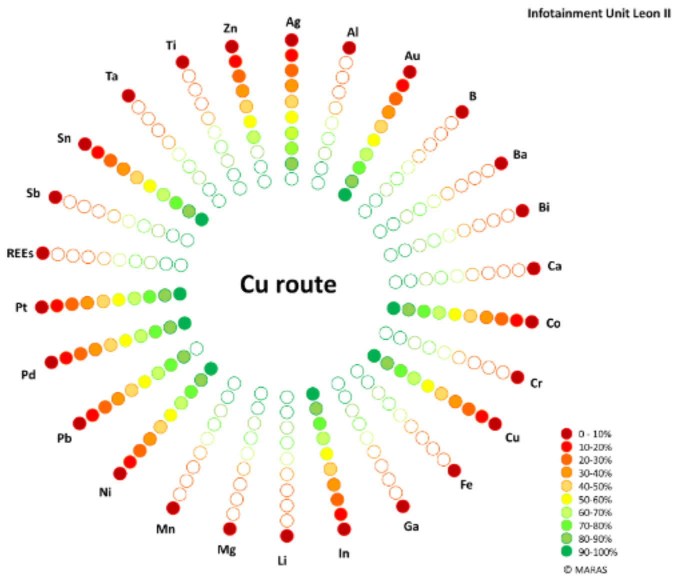
	Evaluation of recycling circular economy systems and product design is performed in the simulation models in terms of mass, energy as well as exergy balances (detail of all streams in kW (both mass, thermal and solution thermodynamics)). The simulation-models within HSC Sim contain an intrinsic link to LCA. This implies that the full detail of recycling simulations is being linked to LCA for the EoL phase. This allows linking of this detail to LCA software/tools as developed within the TREASURE project (GRETA tool) and integration of these values and results into the TREASURE toolbox. This link has not been made within the TREASURE toolbox, however, could be further explored in future, as the Recycling Simulation Models provide the details to do so. The link between recycling simulation models and platform is made through (categorised) input compositional data. Output results (KPIs) as derived from the Simulation Models as well as DfR and disassembly advisory have been defined for the different cases linked to the categorised data sets (however based on the detailed data depth as being part of the simulation models) in order be presented in the platform/Dashboard. As already applied in the past by MARAS, surrogate functions can be created that twin the simulation model. These neural net – AI based tools can then be trained and easily integrated into design tools and the TREASURE platform/toolbox, i.e., implying that the Recycling Module will be an AI tool, which twins the HSC Sim recycling simulation model, as the latter will not be integrated into the platform. This has been done similarly in the past by within the EU 6th framework project SuperLightCar (Krinke et al, 2009). The simulation model calculates all flows, can estimate exergy dissipation but also environmental footprint information. All these data can be integrated into surrogate functions for use in for example design tools and Platform/Toolbox as developed within TREASURE for rapid calculations.
Dependencies with other elements in the project	The Toolbox is developed and exploited in cooperation with the other partners within the Treasure project, being involved in the Digital Toolbox development.
Availability of technical manual	The consultancy and advisory is carried out by MARAS and based on MARAS detailed and extensive industrial and scientific expertise. No technical manual is available; however, MARAS is well experienced in communication with clients on approaches, tools, data requirements and results and their application. The methodologies behind the work of MARAS (as developed within MARAS) are

	widely described and presented in many peer reviewed as well as industry focussed journals and books
Availability of user manual	See above. Also, communications with the partners and transfer of data and results in a simplified format allow for adoption of the Recycling Simulation results in the Digital Toolbox and use of results by users of the Toolbox/Platform
Availability of source code	The source code of the models is developed and owned by MARAS and not made available being IP of MARAS
Availability of binaries	see above

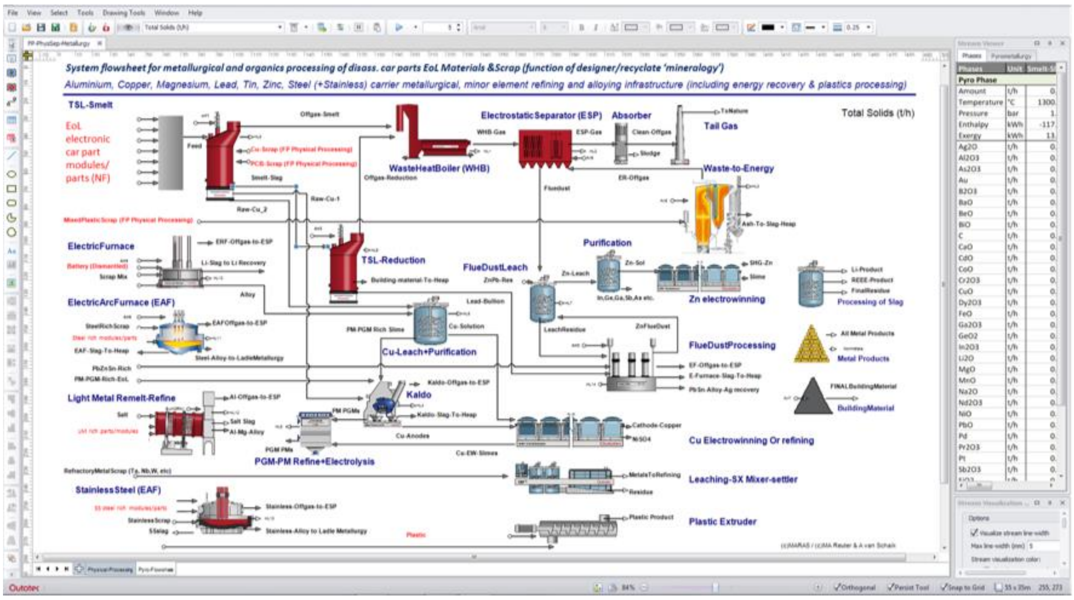
Screenshots of the KER:

Recycling in terms of CE recycling products	Cu processing route	Steel processing	Energy recovery
1. Closed loop CE – high quality products which can go straight back into part or product		No high quality CE products	No high quality CE products
2. Open loop CE to be processed into closed loop CE – intermediate products			 
3. Open loop CE – (intermediate) products for repurposing e.g. as building / construction material etc.	 		
4.Energy recovery from feed	0.15 MWh/t feed	No energy recovery (energy input required in the process)	1.77 MWh/t feed

Example of recycling KPIs (total recycling rate and energy recovery) for different recycling processing options as calculated from recycling process simulation models and visual representation by the REcycling Index (MARAS (c)) as provided to the Digital Toolbox.



Example of recycling KPI for individual material recycling rates available for different recycling processing options as calculated from recycling process simulation models for different design and visual representation thereof by the Material Recycling Flower (MARAS(c)) as provided to the Digital Toolbox.



The metallurgical, energy and plastics processing versatile flowsheet for (electronic) car parts and complex EoL products in the Recycling Process Simulation Model. This is an overview Figure showing how many different flowsheets are linked to maximize the recovery of the many elements, materials, and alloys in a module (see also Figures under KER 9)

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

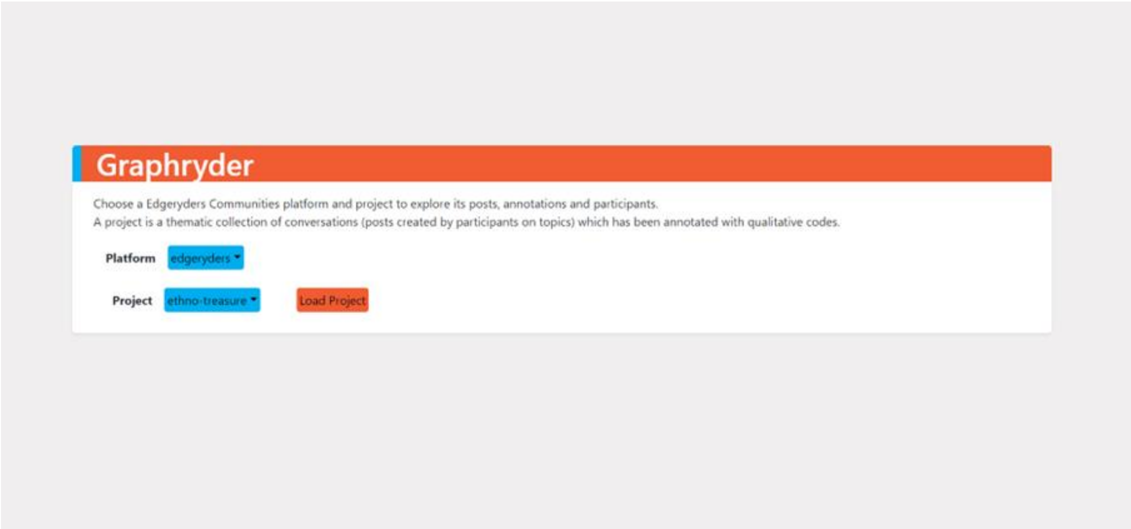
KER#11

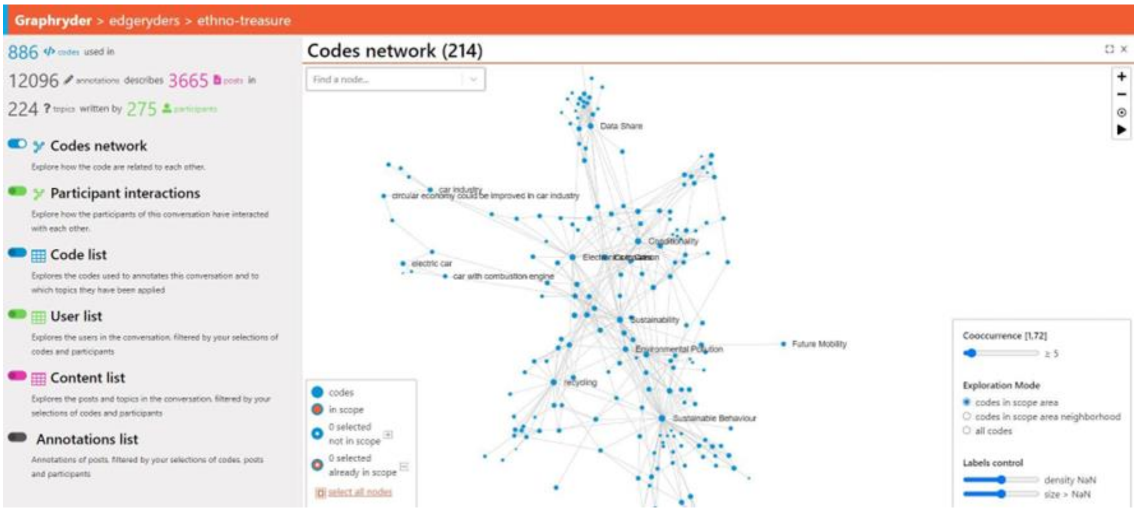
Acronym and full title	Public perception tool
Reference WP and Deliverable	WP2, D2.3
Contact person	Ivan Cukerich
License of the result	Creative Commons Attribution 4.0 International (CC BY 4.0)
Ownership	EDGE
Description	The Edgeryders' Semantic Social Network Analysis (SSNA) is a tool and methodology that allows the implementation of an innovative approach to ethnographic analysis. It is based on the collection of data on a public forum, ethnographic processing and visualisation in the form of graphs. It helps clear the blur of social networks, analysing and summarising data, unveiling usually invisible relations among them and providing timely insights and data with a considerable market value. The tool is open source. The data management plan includes an ethical consent funnel that leads to data collection. The research is limited to the duration of the project. The possible exploitation result is an ongoing iteration of the digital ethnography analysis after the end of the project, making it a standard part of the future TREASURE platform. The longitudinal dimension added to the current research enhances the understanding of the social perception of recycling and circular economy practices in the automotive industry. The introduction to the research through the platform generates opportunities for consultancy. Together with a platform generating revenue which could provide sufficient funding for regular research updates. The mechanism by which this could be possible can include but is not limited to, consultancy packages with specific case studies and dedicated workshops developing the initial findings. Consequently, there would be the potential to build a unique corpus of data from thousands of informants in an event-based ethnography and a public forum.
Major characteristics	*Digital ethnography:* Ethnography is a social science methodology that has evolved to describe cultures. It is well-suited to the task of surfacing hidden assumptions and biases. The innovative part in how we deploy ethnography is our integration of the digital element which enables the analysis of large amounts of qualitative data (corpora) and improves the accountability of the process. Building on prior research done by our group in digital ethnography, the mixed qualitative and quantitative methods approach can lead to informed action planning. This methodology proved to be robust and raised the challenges of

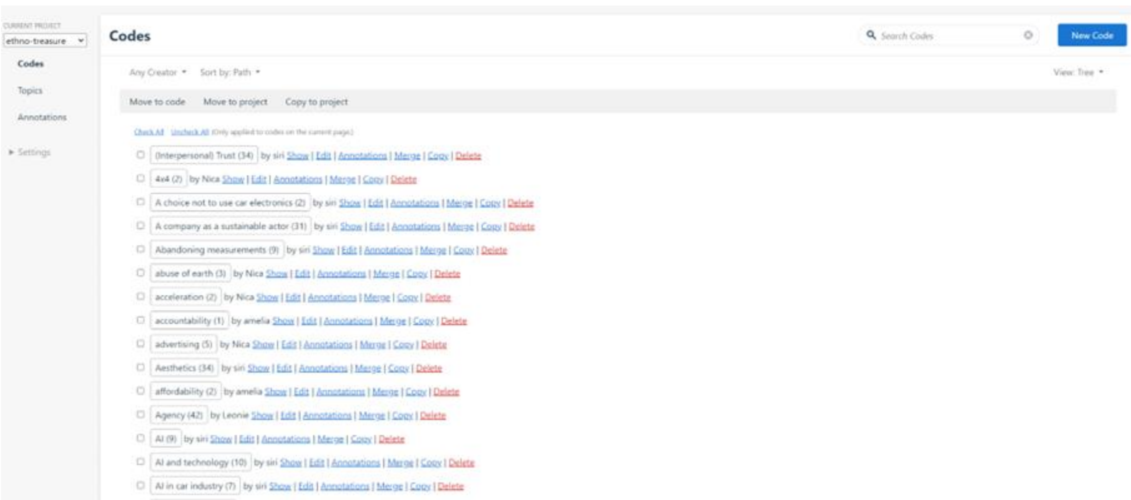
	analysing corpora with thousands of informants and tens of thousands of contributions. This proved valuable in the domain of public consultations (e.g., focused discussions with the general public) or for cooperation building in a strictly limited experts' field (e.g., recyclers working in specific domains of the ELV and CE). Inclusiveness, transparency and adaptability to different levels of research. Inclusiveness derives from the nature of a public forum. Stakeholders and consumers engage and explore their needs, expectations and possibilities while providing information and support. They constitute an issue public. The concept harkens to the political philosopher John Dewey who believed that, in a democracy, competent publics emerge in response to issues by which their members are affected, where expertise is contested and the established frames for problem-solving have broken down. Members of issue publics set out on a quest to inform each other about a given issue and how it should be framed, effectively rendering the participation in such a forum a public consultation. The analysis of this process and its fruits is an inquiry into the results of that consultation. Our method is based on the representation of ethnographic data as networks of co-occurrences between codes. It provides trustable data analysis with better built-in accountability than traditional ethnography and more epistemological humility than is typical of big data analysis. Data structured in digital form (including metadata describing how, when and by whom they were collected) and a partially algorithmic analysis also provide a greater degree of accountability than standard ethnographic practice. The digital element introduces simple verification processes (e.g., inducing a co-occurrence graph and calculating that graph's statistics are easily verifiable steps).
Collaboration with other partners	TXT, SUPSI as hosts of the toolbox, at disposal of other partners for research and consultancy purposes
Availability of technical manual	https://edgeryders.eu/t/graphryder-2-0-manual/16314
Availability of user manual	https://edgeryders.eu/t/graphryder-users-guide/19581 https://edgeryders.eu/t/graphryder-in-treasure-semantic-social-network-analysis/19594 https://edgeryders.eu/t/open-ethnographer-manual/6811
Availability of source code	https://github.com/edgeryders/Graphryder https://edgeryders.eu/annotator/projects/55/codes
Availability of binaries	https://zenodo.org/records/8184389

Screenshots of the KER:

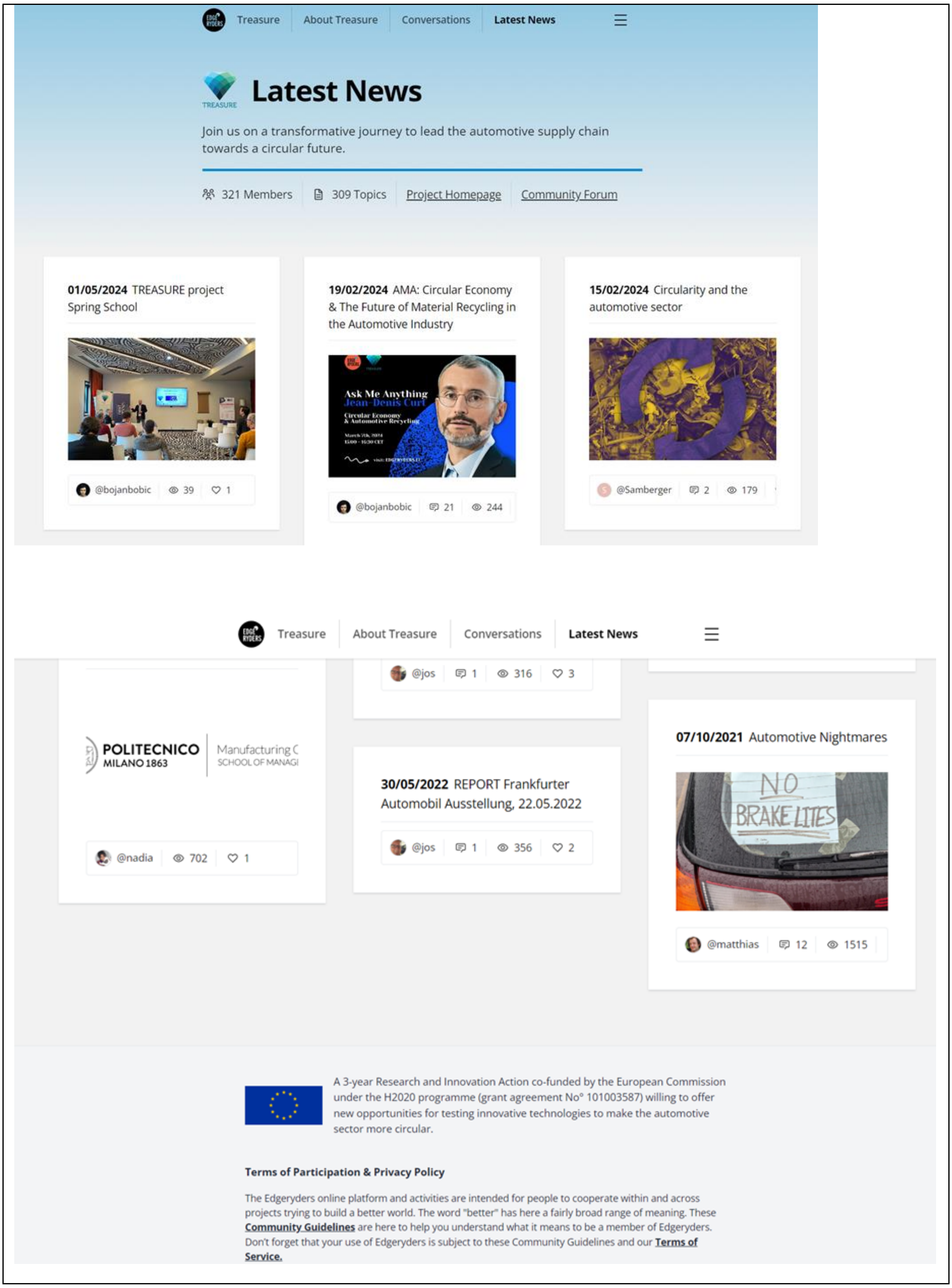
KER#11 is displayed in D2.3 and D4.6







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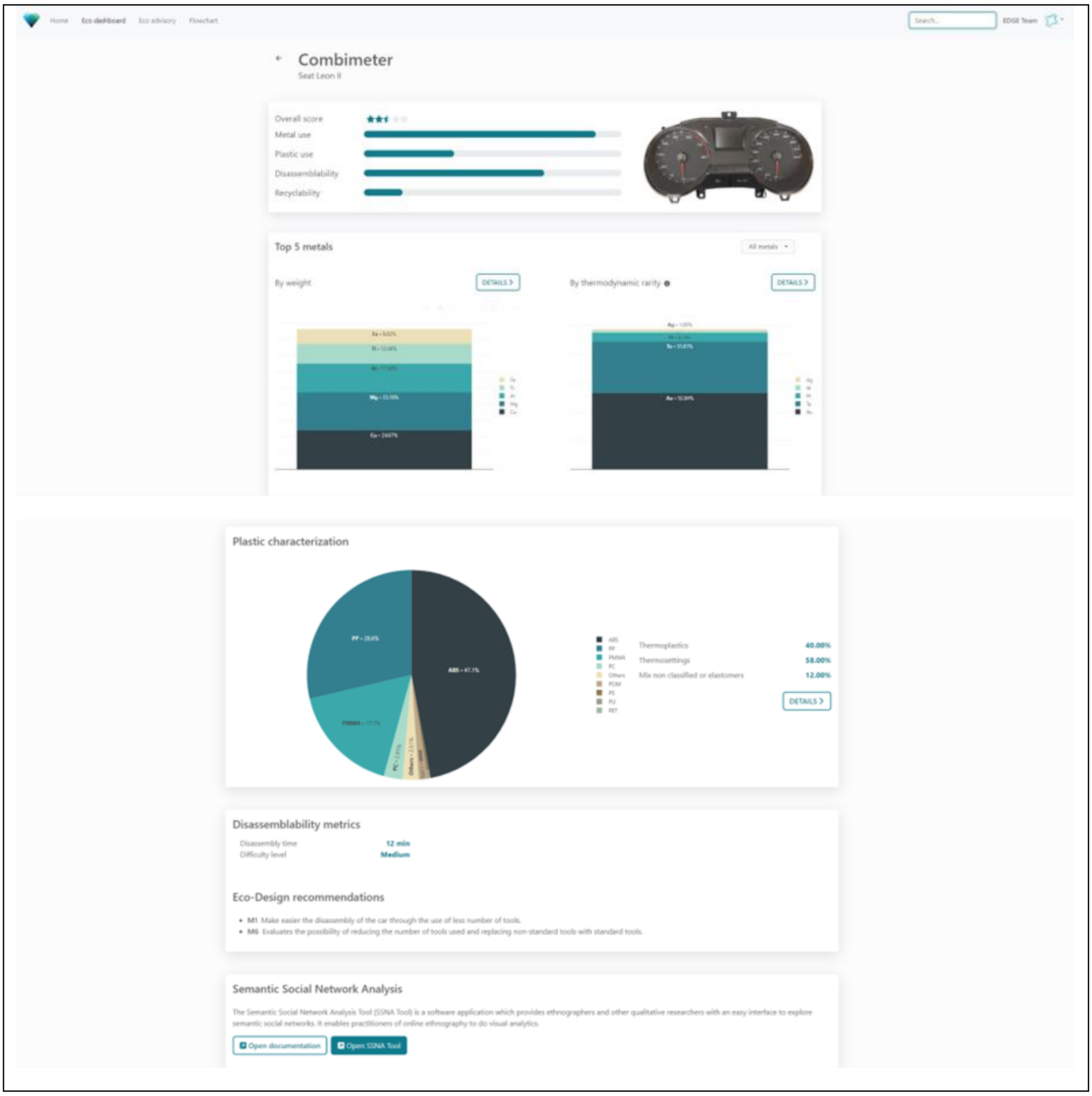
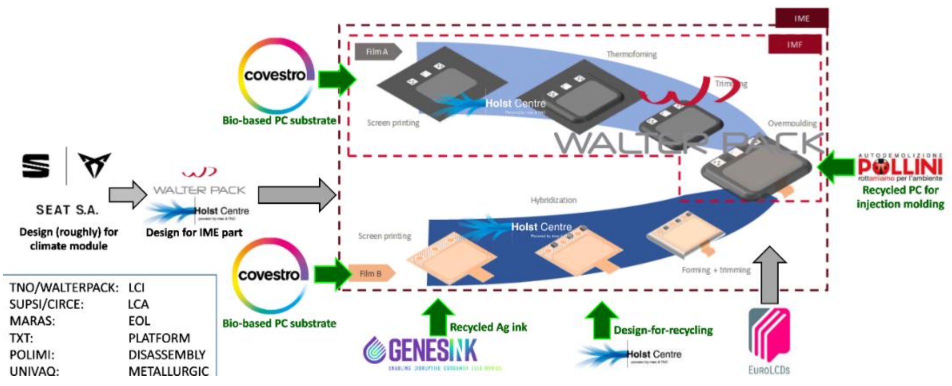


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003587

KER#12

Acronym and full title	Sustainable IME products
Reference WP and Deliverable	WP6, D6.3
Contact person	Laura Del Hoyo
License of the result	Closed source
Ownership	WALTER
Description	Creation of a highly sustainable and recyclable product within the realm of In-Mold Electronics (IME) technology which integrates function into decorative parts. The idea portraited is to create a product that has a reduced carbon footprint, which will help comply with future regulations and specifications coming from car makers. The concept of eco-design is very important here, as one of the key properties of this product, which will greatly influence the exploitation strategy. Eco-design implies that the product must be designed with a sustainable mindset, always with sustainability as a driving force. This activity brings a very clear advantage in terms of sustainability by making the product recyclable, reduce waste and reuse our own waste. However, the benefits do not stop there. It is possible to spare some costs in raw materials or even make business by selling disassembled materials that can later be reused for another purpose. This is really the potential of recycling.
Major characteristics	The IME technology has a double purpose part, be injection molded without the additional processes of gluing, taping or stamping. The double purpose of the part is coming from the fact that the technology allows to integrate function into a decorative part, all at once. Creating an IME is challenging in it of itself, let alone be it sustainable and recyclable, but this has been tackled during the TREASURE project. The premises considered are the following: a. Plastic materials: Reuse them from a recyclable source (if it is coming from the own waste produced at WP even better). Alternatively, if this is not an option, the product could be made more sustainable overall if the materials are bio-based. b. Silver ink: One of the key elements of this project is that the silver ink used to print the conductive features, will be coming from recycled IME parts provided, empowering the circular economy.

	c. Design for recycling: The part will be designed in a way that the whole construction of the product can be disassembled, creating a part that is ready to be recycled, given the correct instruction. However, this is where the TREASURE platform would be very beneficial. Through these improvements, the objective is to add sustainable value to customers, creating a product that is up to date, complex, technological and sustainable. Exactly the kind of product that anyone would like to exploit.
Collaboration with other partners	As experts in Film Insert Molding technology for the past 20 years, we continue to advance innovation by focusing on the integration of embedded electronics. To this end, we continue to engage in local, state, and European funding projects with partners and establish relationships and alliances such as the recently announced one with the Canadian company E2IP. All of this is to introduce this technology into the automotive market and offer it to OEMs. https://www.linkedin.com/posts/walter-pack-group_antolin-e2ip-and-walterpack-join-forces-activity-7142549422067953666-hvm9?utm_source=share&utm_medium=member_desktop
Availability of technical manual	None.
Availability of user manual	None.
Availability of source code	Not applicable in this case.
Availability of binaries	None.
Screenshots of the KER: 	

KER#13

Acronym and full title	Digital Tool Framework
Reference WP and Deliverable	WP4, D4.7, D4.8, D4.9, D4.10
Contact person	Mattia Calabresi
License of the result	Closed source
Ownership	TXT
Description	The digital tool framework is a web-based multi-layered data-driven solution developed to exchange valuable information and knowledge for a proper implementation of CE and sustainability-oriented practices along the automotive value chain. Thanks to the Data Importer and Data Lake internal components, it provided aggregated and enriched intelligence from data ingested from external sources (mainly MISS database) concerning detailed car part material composition, disassembly procedures and eco-design suggestions. Moreover, through the Service Layer, it represents the infrastructural backbone for the provision of addition information on recovery rate, recyclability routes, economic and social impact assessment are presented. More in detail, the digital tool framework comprises the following modules: – A Disassemblability module providing information on critical and valuable car parts to be disassembled and useful disassembly instructions. – A Recyclability module providing information based on quantification of the recycling performance (quantified KPIs) on the recycling/recovery rates of car and electronics raw materials/elements/compounds (including losses and emissions) and providing advice on best recycling routes and processes for optimal recovery and disassembly intensity. – An Eco-design module providing information on hardware components, valuable recommendations for the design phase based on KPI's as derived from the disassembly and recycling module. For each module the digital tool framework includes the Advisory section that provides guidelines and intelligence for informed decision making in terms of eco-design, disassembly, and recycling processes.

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

Major characteristics	The digital tool framework comprises the following functionalities: – data provision in an aggregated form with charts and text – secure log in – data storage Data editing and integration with additional information
Collaborations with other partners	MARAS, UNIZAR, SUPSI, EDGE
Availability of technical manual	Final documentation to be made available after the final release.
Availability of user manual	Final documentation to be made available after the final release.
Availability of source code	Closed
Availability of binaries	
Screenshots of the KER: *N/A* Closed	

KER#14

Acronym and full title	AR/VR Disassembly Procedure
Reference WP and Deliverable	WP4 - D4.7, D4.8
Contact person	Michele Sesana, Mattia Calabresi, Veronica Antonello
License of the result	Closed source
Ownership	TXT
Description	WEAVR is a proprietary software toolbox developed to streamline the design and development of virtual training systems. The WEAVR Platform is exploited by dismantlers/disassembly operators in the Disassemblability module allowing operators to disassemble car parts/components exploiting augmented reality procedures. The objective of the WEAVR platform is to simplify the disassembly operations performed respectively in the Disassemblability module, leveraging an innovative virtual/augmented reality platform enabling different actors to create, manage and execute augmented procedures on a wide variety of physical devices.

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

Major characteristics	The main advantages that the TREASURE platform gains throughout the usage of WEAVR boil down to a general improvement of the activity performed by the operator, that is now assisted by ad-hoc procedures during his typical working activity. Specifically, the WEAVR platform performs the following tasks: • Speed up the task's execution time: by providing detailed and easy-to-follow steps that the operator carries out in a precise order, avoiding losing time performing alternative operations in a suboptimal order. • Reduce worker training time: by providing a virtual training environment in which the operator can receive feedback on the tasks performed, reducing the impact of errors and avoiding potential damage to physical components/materials. Increase worker understanding of the component/part: by allowing the operator to access an interactive model of the component/part that is being disassembled, with the possibility to over impose augmented information on top of the real component (e.g., displaying a transparent model of the part to be disassembled highlighting internal modules/sub-parts).
Collaborations with other partners	UNIZAR for disassembly analysis
Availability of technical manual	Final documentation available for users
Availability of user manual	Final documentation available for users
Availability of source code	Closed source
Availability of binaries	Closed source
Screenshots of the KER n.a.	

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

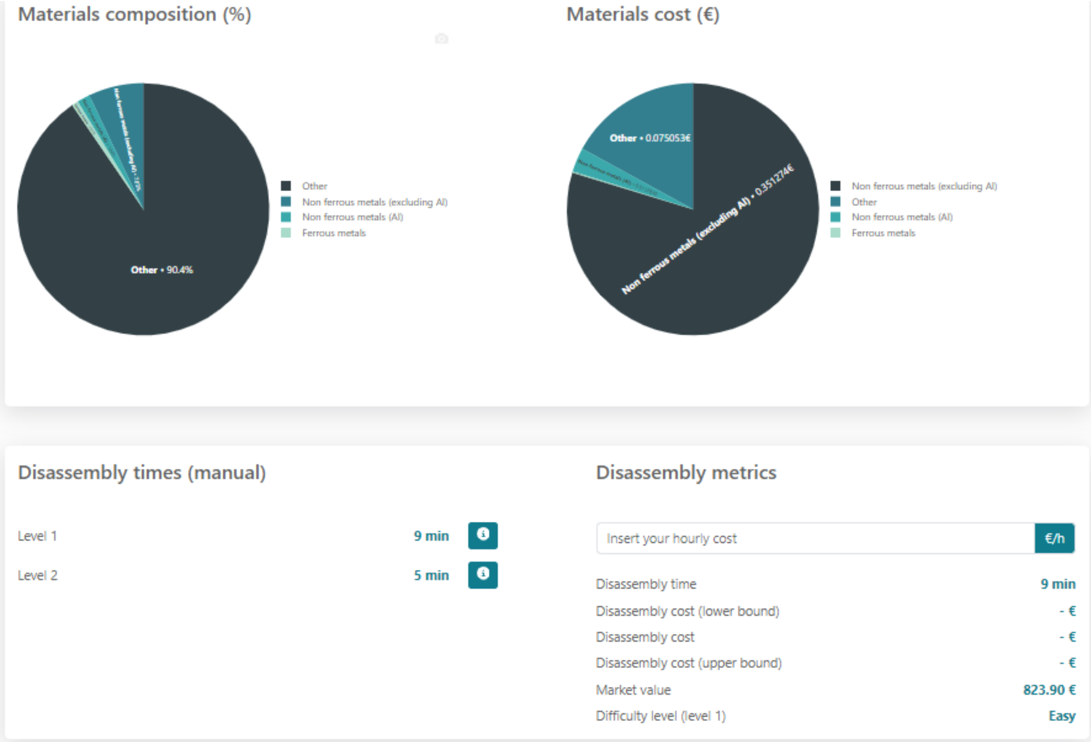
KER#15

Acronym and full title	Disassemblability assessment methodology
Reference WP and Deliverable	WP3, D3.1
Contact person	Alicia Valero, Ricardo Magdalena, Abel Ortego
License of the result	Creative Commons
Ownership	UNIZAR
Description	UNIZAR brought to the consortium a thermodynamic theory used to assess the physical criticality of raw materials. This theory has been published in several open journals and therefore is freely available. Within the project, the thermodynamic theory has been further developed to produce a "circularity KPI", aimed at assessing the level of circularity achieved through the different pilots created within TREASURE. This KPI is calculated by comparing the so-called thermodynamic rarity before and after every stage of the pilot plants, allowing for the calculation of the rarity lost at each point. Thermodynamic rarity is an indicator grounded in the second law of thermodynamics, evaluating the physical quality of materials concerning their scarcity in the Earth's crust and the energy intensity associated with their extraction and refining. Its advantage over mass-based indicators lies in its ability to avoid comparing dissimilar materials, recognizing that, for instance, a ton of iron holds a different perceived value than a ton of gold. Unlike monetary indicators, it remains stable despite market volatilities and holds universal applicability. Incorporating the thermodynamic perspective into the results of the various recycling processes and situations involving metals, it is possible to assess the recyclability in terms of recovered materials, considering their physical quality. Built upon the concept of rarity, a methodology has been developed to evaluate the disassembly of car parts. This methodology combines the determination of disassembly times, and thus costs, with the physical value (thermodynamic rarity) of the recovered materials. It also establishes various disassembly levels and records information on the required tools and difficulty level. Finally, based on the results obtained, eco-design options are proposed, aiming for a more efficient and effective approach to recovering the identified critical components.

	The obtained results serve not only for publishing articles in scientific journals but also for conducting future lectures and training sessions, either to students or experts in the field. Moreover, the acquired knowledge can be used as a foundation for future MSc theses and enable deeper studies for PhD students. This multifaceted utility underscores the significance of the research endeavors, facilitating both academic dissemination and the advancement of higher education pursuits. Additionally, the methodology developed will be utilized for circularity assessments of other car parts, such as batteries or chargers, as well as for other products like mobile phones or laptops within further R&D projects at both national and European levels.
Major characteristics	The methodology's procedure starts with the chemical characterisation of the given product (in this case a car part). The starting point is the material sheet provided by the manufacturer (i.e. MISS database). As a result of the characterisation, the composition in terms of elements and major subcomponents of the car part is provided. This composition is then converted into rarity values, so that critical raw materials are given a major weight based on the scarcity degree of the crust and the difficulty to mine and refine the metals. In this way, the most critical parts of the product can be identified and the disassembly levels to reach the valuable parts can be obtained. After manual disassembly (it can also be accomplished with the help of a cobot or robot), several parameters are recorded such as disassembly time, required tools or difficulty level to carry out the process. With this, disassembly times and costs versus recovered materials can be obtained. Through analysis of the outputs from the disassembly process, potential improvements can be identified to boost process efficiency and recovery effectiveness. A decision matrix facilitates the generation of eco-design proposals to both: reduce the criticality of the product in terms of the use of valuable materials and 2) improve the recyclability by improving the disasssemblability. Combined with a recyclability analysis developed by MARAS, the circularity KPI can be calculated, which serves as a unique indicator to assess the circularity potential that the given product has.
Dependencies with other elements in the project	None
Availability of technical manual	No
Availability of user manual	No
Availability of source code	No

Availability of binaries	No

Screenshots of the KER:



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KER#16

Acronym and full title	CWA
Reference WP and Deliverable	WP8
Contact person	Cristina Di Maria
License of the result	CEN CENELEC + Project Partners
Ownership	UNI
Description	A CEN Workshop Agreement (CWA) is a consensus-based document developed through a CEN Workshop, which is an open platform allowing direct participation from interested stakeholders. A CWA addresses immediate market needs and can be produced quickly, typically within 10 to 12 months. It is less formal than a European Standard and does not require formal national voting. Once consensus is achieved, the CWA is published to facilitate innovation and knowledge transfer.
Major characteristics	• **Quick Development**: CWAs can be developed quickly, typically within 10 to 12 months, to address immediate market needs. • **Open and Transparent Process**: The development process is open and involves direct participation from all interested parties. • **Consensus-Based**: CWAs reach consensus among European stakeholders on specific technical or organizational matters. • **Informal**: They are less formal than European Standards and do not require formal national voting. • **Flexible Tool**: CWAs are flexible tools for innovation and knowledge transfer in various fields
Collaborations with other partners	All partners of the project participated in defining the CEN Workshop Agreement (CWA). The development process of a CWA is open and transparent, allowing direct involvement from all interested parties, ensuring a broad consensus among stakeholders.
Availability of technical manual	Not available
Availability of user manual	Not available
Availability of source code	Not available
Availability of binaries	Not available
Screenshots of the KER	

Draft Project plan for the CEN Workshop TREASURE on "A methodology to improve the recyclability rate of Critical Raw Materials from cars"

Requests to participate in the Workshop and/or comments on the project plan are to be submitted by 27 November 2023 to mario.gallo@uni.com[1]

Recipients of this project plan are kindly requested to name all patent rights known to them to be relevant to the Workshop and to make available all supporting documents.

Milan, 2023.10.06 (version 1)

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

3. Individual exploitation strategy

3.1. Introduction

This chapter focuses on the "HOW" the exploitation will be individually executed by project partners. The Individual Exploitation is the process by which each project partner takes advantages based on the foreground produced in the project. As part of the exploitation planning, each TREASURE partner has elaborated on the potential impact of the project and the commercial/societal value the outcomes will have in its company strategy. The objectives of this chapter are:

- to identify the KERs of the TREASURE project to be used in individual exploitation;
- to plan the individual exploitation in terms of actions to be done and targets.

Mapping individual partners' exploitation intentions show the following general trends:

- Academic partners are university and research centres interested in consultancy, in creating scientific publications relating to their results and in developing new interdisciplinary research lines;
- ICT and consulting service-oriented partners are interested in selling either software licenses or consulting services related to either software or specific knowledge by integrating results in the existing portfolio to provide new opportunities to customers. Clearly where exploitation opportunities are present, these partners are interested in exploiting different granularity of results from platforms to packages to single assets which might be interesting for their clients/business partners;
- Industrial partners are planning to exploit TREASURE platforms for their own usage, but also – jointly with other partners – to extend it to other organizations in their markets and other organisations they do business with (e.g. their suppliers or partners). Sector Organisations are planning to exploit TREASURE instantiations in the form of industry specific Solutions for the related sector.

Collectively, the consortium has the necessary competences to:

- successfully deploy and eventually market the results of the project;
- provide a full range of complementary services (IT infrastructure, software, methodologies, content, business processes) with total coverage and high credibility.

In the following sections the individual exploitation strategies are described for each partner. For reading convenience the next table provides the partners list, short name as indicated in the context of this deliverable, and relevant category.

Table 2. List of TREASURE partners performing an individual exploitation strategy

Partner	Acronym	Ref. Package	Category
Politecnico di Milano	POLIMI	Methodology	Academic
Nederlandse Organisatie Voor Toegepast Natuurwetenschappelijk Onderzoek	TNO	Methodology	Academic
Scuola universitaria professionale della Svizzera italiana	SUPSI	Methodology	Academic
Università degli Studi dell'Aquila	UNIVAQ	Methodology	Academic
Material Recycling and Sustainability (MARAS) B.V.	MARAS	Methodology	Service
Edgeryders OU	EDGE	Methodology	Service
Walter Pack SL	WALTER	Digital	Industrial
Universidad de Zaragoza	UNIZAR	Methodology	Academic

The exploitation of the UNI's KER is described in D8.4.

3.2.POLIMI

Currently, POLIMI sees the following exploitation streams:

- **Horizon Europe future projects** in the current Horizon Europe 2022-2024 work programme and contributing to symbiosis with EFFRA to the definition of new FP9 CE-related priorities and objectives. In particular, inside the Connected Factories cluster and CSA, POLIMI has been the ideator and the principal supporter of the third persona named "Collaborative Product-Service Factories", where TREASURE concepts and methods have been projected towards 2025 scenarios and platform-data-skill-collaboration pathways to the future.
- **Industry 4.0 Observatory** which, inside the POLIMI observatory https://www.osservatori.net/ww_en/observatories/observatories/industry-4.0 direction oversees monitoring and analysing how Italian national enterprises support the improvement of their innovation processes concerned with Industry 4.0. The focus of the I4.0 Observatory is to understand to what extent new enabling technologies could represent a disruptive / progressive innovation in promoting new business models. TREASURE is contributing to the I4.0 by introducing the peculiar challenges of PSS design into such a well-established successful scientific environment and significant benchmarking statistical basis.
- **I4.0 Lab POLIMI** which is a "Training Factory" for Students implemented in collaboration with FESTO Italy since 3Q 2017. In particular, machinery produces real world data to feed advanced manufacturing intelligence applications (optimisation, energy management) in the hands of students' configuration and experimentation. TREASURE WP5 and WP6 as well as the POLLINI use case could enrich the environment with new tools and experimental facilities. The WP6 deployment into the I4.0 Lab has been recently completed and first applicative results can be shown in dedicated videos.
- **Methodological Package**. In the longer term, POLIMI is aiming at developing educational services about circular services and circular manufacturing to the manufacturing industries especially SMEs in Lombardy and through AFIL (Lombardy Intelligent Factory Association http://www.afil.it/) working groups. This could also lead to POLIMI spin-offing projects in this promising field.

3.3.TNO

The key enabling results exploited by TNO concerns consultancy and training services on the topic of design-for-recycling for printed electronics in general, but in-mold structural electronics specifically **(KER 3)**.

Intellectual property was filed before the Treasure project: WO2022220688 and was further put into practice during the Treasure project.

Additional work is required:

1. Future research work is focused on (but not limited to):
    - Assessing the advantages and dismantling of dismantling to a fuller extent
    - Impact analysis of the use of the dismantling layer on production, costs, environmental impacts and especially end-of-life
    - Assessing the environmental impacts of physical recycling
    - Increasing TRL level, thereby enabling commercialization
2. Future training/consultancy work is focused on (but not limited to):
    - Helping companies transition from PCB-based electronics to printed electronics based sustainable devices, thereby contributing to the goals of the Green Deal, complying to EU Environmental laws and having a potential competitive advantage
    - Helping companies understand and use design-for-recycling principles in their printed electronics applications
3. Future development of new products (physical/digital):

- Our expertise will mostly contribute to reducing the environmental impact of highly integrated parts based on IME for automotive. TNO will not produce new products but will enable e.g. automotive Tier suppliers and OEMs to commercialize IME and comply with future legal requirements (ESPR), enforcing durability, recyclability and repairability.
- TRL4 (Technology validated in laboratory) validation has been accomplished during the Treasure project, but TRL5+ requires a more extensive collaboration with automotive Tier suppliers. Talks with WalterPack are underway for such exploitations.

3.4.SUPSI

As a higher education institution, SUPSI inherently focuses on research and education, thus traditional services typically provided by a software company, such as customer support, marketing, and technical maintenance for software products, are beyond SUPSI core competencies.

With reference to the **Sustainability & Circularity Assessment methodology (KER 4)** developed within TREASURE project, has been classified as a Consultancy and Training services KER according to the business model taxonomy.

Below, we delve into the strategic targets and outline the key benefits we aim to achieve, laying the groundwork for a well-defined path to success.

Target groups & entities: Small and medium-sized enterprises (SMEs) looking to integrate sustainable practices into their business; startups interested in adopting sustainable and circular principles from the outset; management consulting firms wanting to incorporate sustainability and circularity into their strategic consulting services; educational programs focused on sustainability studies, environmental science, or circular economy initiatives.

Examples of industries: education, automotive, manufacturing companies.

Examples of target companies: Swiss universities, car designers, manufacturers, dismantler.

Potential competitors: Competitors would likely include local and regional consultancy firms specializing in environmental and sustainability consulting for small businesses. Examples might include smaller, niche consulting practices that offer personalized services, potentially even individual consultants or academic departments offering consulting and training services as part of their outreach or research activities.

Promotion policy includes:

- Networking and Collaboration: Foster partnerships with industry associations and sustainability networks to expand outreach and access potential clients. Collaborate with other research institutions and consultancy firms to leverage their networks and promote the methodology collectively.
- Social Media Presence: Utilize social media platforms (e.g., LinkedIn) to share updates, insights, and success stories.
- Webinars and Online Workshops: Host webinars and online workshops to introduce the methodology to new audience. Offer free introductory sessions to attract participants and showcase the value of the training and consultancy services.
- Publication and Thought Leadership: Publish articles, whitepapers, and case studies in industry journals, academic publications, and online platforms to establish thought

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leadership. Position SUPSI experts as leading voices in the field of sustainability and circularity assessment.

With reference to **The Sustainability & Circularity Advisory methodology (KER 5)** (able to support decision-making) the approach is specifically designed to facilitate decision-making processes related to disassembly, recycling, and eco-design of electronic components in the automotive industry.

The results will be used:

- In the individual exploitation, the methodology is integrated in the SUPSI sustainability tool, and the exploitation strategy may include the use of the methodology for the same aims (consultancy, teaching, research, licensing) of KER 4, targeting the same end-users (industries, students, researchers, consultancy companies).
  In the joint exploitation with TXT

Finally, the **GRETA tool (KER 6)** can be used as a support to consulting and training activity (so classified as a "Consultancy and Training services" KER according to the business model taxonomy), or sold as a software tool (alone or part of a toolkit or of a TREASURE platform), so classified as a "Digital service" KER.

SUPSI oversees directly only exploitation regarding **Software platform for consulting services and manufacturing companies** and **Consulting services for SMEs**.

To effectively commercialize the GRETA platform, SUPSI is currently evaluating two strategic approaches to bridge this gap and successfully introduce GRETA to the market: the foundation of a spin-off company and the establishment of a licensing agreement with an established software retailer or developer. Over the next two years, SUPSI anticipates developing a more defined strategy and making a decisive selection between these options. This strategic exploration aims to ensure that the GRETA platform is supported by the necessary commercial infrastructure to maximize its market potential and impact.

SUPSI is planning different paths to promote the GRETA platform. Those paths are relevant both for Software platform for consulting services and manufacturing companies and Consulting services for SMEs. So far, word-of-mouth and direct contacts established also within research projects have been the main ways used to let potential users know GRETA. In the coming two years, a more structured promotion strategy has to be developed. This strategy has to focus on the platform unique features and benefits to overcome certain challenges that have been already identified.

Challenge 1: Differentiating in a crowded market. Standing out in a market filled with sustainability and circularity assessment tools requires to emphasize GRETA's unique selling points, such as its specific methodologies, integration capabilities, and leverage on the "streamline sustainability" motto, resulting in a democratized access to sustainability-based decision making also for those not expert in sustainability assessment topics.

Challenge 2: Communicating complex value propositions. Effectively communicating the technical and specialized benefits of GRETA to a diverse audience, including those who may not have a deep understanding of sustainability metrics is an actual challenge. For this reason, we need to develop clear, accessible messaging that conveys the benefits of GRETA in practical terms. Use visual aids, video tutorials, and interactive webinars to make its functionalities more understandable and engaging.

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Challenge 3: Building and maintaining user engagement. Ensuring users not only adopt but also continuously engage with the platform can be achieved offering excellent customer support, create a user community through forums or social media groups, and provide regular updates on new features or use cases. Engaging with users for feedback and suggestions can foster a sense of community and loyalty.

Challenge 4: Navigating licensing and collaboration agreements. Establishing partnerships or licensing agreements that allow for market expansion without compromising the platform's integrity or the university's intellectual property has to be carefully targeted. Agreements need to be found that align with SUPSI's goals and GRETA's developmental roadmap, ensuring partners are committed to mutual success and respect for intellectual property rights.

Challenge 5: Reaching the right audience. Identifying and connecting with the most relevant segments of the target market, including industries, businesses, and academic institutions that can benefit most from GRETA requires to use targeted marketing tactics, including SEO, content marketing focused on industry-specific issues, and participation in specialized forums or events. Collaboration with industry influencers or thought leaders can also help reach a wider yet relevant audience. Those activities are not easily manageable by a university, so it is reasonable to find another entity in charge of them.

3.5.UNIVAQ

UNIVAQ in the last 25 years has been engaged in the development of innovative hydrometallurgical operations to recover base, precious and critical metals from e-waste and other kind of industrial waste. To complete the background UNIVAQ has been involved in several projects in the ambit of EU calls like LIFE BITMAPS, FENIX, PEACOC, NEW-RE, INSPIREE, PASSENGER, and GRAPHIREC. In addition, UNIVAQ supports recycling companies in consultancy services in the field of industrial waste and wastewater treatment. Considering the developed knowledge UNIVAQ can carry out research activities in the field of Circular Economy giving a wider vision of this concept with a holistic approach. In addition, the external partners SWE and BFC support UNIVAQ in basic engineering design and plant construction.
UNIVAQ wants to enhance the hydrometallurgical process development for the recycling of strategic/crucial metals (precious, base, and critical) from PCBs, LCDs, and IMSEs according to an approach that aims at minimizing wastewater production (**KER 7**) and to support the customer in the construction of the turn-key pilot & industrial plant (**KER 8**).
Intellectual property was filed before the Treasure project on the recycling of PCBs with different methods: Gold-REC 1 (International Publication number: WO2018/215967) and Gold-REC 2 (International Publication number: WO2019/229632). Within this project, further advances have been achieved on this topic, which has allowed UNIVAQ to improve its expertise in increasing metal extraction yields. In addition, a patent is pending on the results obtained in the ambit of the Treasure project for the hydrometallurgical recycling of silver and indium from IMSEs, LCDs, and other materials with similar characteristics.

About **KER 7** is a **consultancy service** aimed at recycling companies and dismantlers that require assistance in improving the management of end-of-life products. The purpose is to reduce disposal costs thanks to the extraction of valuable metals that generate a revenue stream. This is not only an economic benefit but also contributes to resource conservation.
KER 8 is an **industrial product** that can be realized as a direct result of a consulting activity carried out in the ambit of KER 7. UNIVAQ intends to exploit this industrial technology in collaboration

with external companies. Smart Waste Engineering s.r.l. (SWE) can contribute to the field of process design and sustainable and innovative environmental processes taking advantage of its expertise. BFC Sistemi s.r.l. (BFC) specializes in the development and construction of hydrometallurgical pilot or industrial plants. With years of experience in the field, BFC has been involved in the successful construction and reconfiguration of the hydrometallurgical pilot plant, which played a crucial role in advancing Treasure activities.
With the realization of the plant, UNIVAQ will also establish agreements with customers for the sale of the essential patent necessary for carrying out the process on the hydrometallurgical plant. Various selling strategies can be adopted depending on whether the item is exclusive or not. Additionally, royalties can be defined based on customer revenue from recovered metals.
Marketing and promotion to increase awareness of the services offered and attract potential customers will be developed through the following channels: scientific publications, workshops participation, webinars, collaborations with universities and research institutions, collaborations in the ambit of future EU calls, and social media. In addition, the existing hydrometallurgical pilot plant will have a key role in showing the innovation potential of the findings to customers and demonstrating the hydrometallurgical processes at TRL5.
Potential limitations are related to the competitors that are essentially the EU pyrometallurgical plants such as Umicore, Aurubis, and Boliden, which deal with the recycling of various types of industrial waste. Moreover, some restrictions arise from the significant variability in the content of valuable metals in industrial waste, even among the same device and car components based on their model or production year. As a result, the consultancy service provided under KER 7 cannot always assure the creation of an economically feasible hydrometallurgical process.

3.6. MARAS

Van Schaik and Reuter (MARAS B.V.) have developed over the last 25 years innovative physics-based process simulation models, which assess, quantify, and improve/optimize the resource efficiency of (recycling) processing systems of complex multi-material products. These models provide a digital twin of disassembly, liberation and sorting processing linked to Best Available Techniques (BAT) in metallurgical recycling processing infrastructures. These models and tools build on the product-centric approach to recycling as defined and coined by Reuter and Van Schaik 2012, 2015) to provide the platform for assessing and optimizing the recovery of materials and energy from these designer ‘minerals’ having the depth and rigor to capture the characteristics and details required to understand recycling of materials from complex interconnected multi-material products.

Many industry and consultancy projects as performed by MARAS over the years, combined with a continuous development and innovation of the methodologies, tools and models and definition of Recycling and Circularity Indicators, have proven the applicability of the knowhow and consultancy of MARAS for industry and consultancy. The innovative nature of the proposed business provides the opportunity to truly make a positive change towards a more circular approach of recycling and industry, in a period in which the need of change of society towards more responsible, sustainable, and circular behaviour is getting a much wider understanding in society, industry and regulation. Above all the approaches used provides the much-needed economic basis to understand the viability of solutions. This is a key strength as well that leads to a significant opportunity.

The fact that MARAS is at the forefront of innovation, and that the need for quantification and tangible results is increasing, provides opportunities to further develop the proposed business. As the work from MARAS and the proposed business combines both industry and scientific innovation and application, the work can also be applied to teach young people in universities and schools as well as to train industry in a more rigorous approach to recycling and sustainability.

The links and contacts to industry and universities as well as linking up with partners within the TREASURE project and demonstration the work and business in this project, is supporting the opportunities of the business of MARAS. The members of MARAS work in industry, in academia and link this to consultancy. This is a strong and unique opportunity.

The expert knowledge and Recycling simulation model **(KER 9)** provide the basis for exploitation also through the Digital Toolbox **(KER 10)** by providing consultancy, calculations and advisory for the EoL phase of products, as well as for DfR and optimal design of recycling systems (including balancing disassembly with recycling processing) and linking up with other disciplines within the field of CE within this Toolbox.

Potential targets and benefits of the REC and ECO module based on the detailed Recycling Simulation Models as developed by MARAS within the digital toolbox are:

Dismantling/recycling industry

Consultancy and advisory to dismantling/recycling industry such as car dismantling companies and WEEE recycling (shredding and sorting) plants on additional disassembly or the effect thereof to optimize recycling. This is supported through the Digital Toolbox as developed in Treasure, in the results of the recycling assessment and advisory as derived from the Recycling Simulation Models are presented in an easy to use and grasp manner through the REC module with a direct feedback to the user requests as defined by the user in the Digital, however being derived on a rigorous basis

Recycling industry (shredding/sorting plants for automotive and WEEE recycling)

Consultancy/advisory on most optimal recycling flowsheet architecture (based on the best available technologies at industrial level including dismantling, physical separation and sorting, as well as extractive metallurgy and processing) – this can be applied to develop flowsheets for different products, design alternatives, disassembly scenarios and recycling objectives, etc. on same basis and principles and described under first point

LCA community

- Not yet explored and included in the Digital Toolbox, but the Recycling Simulation Model allow for the link of recycling process simulation and all mass and exergy flows to LCA in order to perform product design and recycling technology based environmental EoL assessment which can discern between different designs (alternatives) and processing options (unique product driven recycling fingerprint).
- This could be adopted in the Digital Toolbox
- Provide input/consultancy/advisory to LCA community (both industry and academic development) on how to link
- Especially of interest is the exergetic basis of the MARAS simulation models, that provides clarity on what the possible baseline of the complete material supply chain is. This provides

the critical clarity on financial viability of the supply chains as the simulation basis is based on the physics of the industrial reality.

Consultancy to OEMs (both automotive and WEEE) (contacts in automotive and WEEE (e.g. Fairphone) OEMs exist)

- Recycling assessment, calculation of recycling rates, recycling KPIs and CE indicators
- Design for Recycling assessment and advisory: feedback and input to eco-designers based on metallurgical incompatibilities (qualitative from the Metal Wheel) and quantitatively based on the findings of the recycling simulations and derived insights into recoveries and losses of materials/elements/compounds of these car parts (ECO module)
- Evaluation of recycling circular economy systems and product design in terms of mass, energy and exergy based KPIs

Training/teaching and education

Training and education of MSc and PhD students. We already provide extensive under- and post-graduate course using the types of simulation approaches developed in Treasure. E.g. Alcasim is an EIT Rawmaterials continuing education course (https://www.aaltoee.fi/en/lifewide-learning/programs/eit-alcasim-advanced-lca-simulation) that teaches simulation-based LCA, as followed in TREASURE. In addition regularly MARAS involved member teaches this at TU Bergakademie Freiberg Germany to over 60 students, the participant number of the 80h block course in 2023.

Regulators/policy makers/ NGO's

Physics-based recycling standards, development of industry relevant and ambitious and realistic recycling targets, providing insights/consultancy/know-how on true performance, possibilities and limits of recycling, sustainability, and circularity on a rigorous physics basis. Projects/links already performed/existing with JRC. It is interesting to note that at present there is a report being developed for the JRC in Ispra (Directorate General Sustainability EC) by members of MARAS, that will highlight for example the importance of having simulation-based i.e. physics-based analysis of supply chains in order to be able to understand the physics limits of supply chains.

The consultancy, advisory and training of this KER as developed and exploited by MARAS B.V. is innovative and unique in the field and differs from existing approaches based on its rigour, physic basis, and both scientific and industry-based expertise, which does not exist in this field.

The potential market is world-wide/global. Consultancy and training can be applied at National, European, and global level. This is already happening with the MARAS expertise as mentioned above.

Teaching services will be extended based on existing network and professorship of Prof. Markus Reuter at various universities and contacts. This has been high-lighted above.

Consultancy services will be built upon existing and related network in industry based on long-term activities and established expertise and unique established image and recognition of MARAS. This will bring the important link between (modular) product design, end-of-life, sorting/physical separation and process metallurgy and materials processing.

Work and expertise will be promoted and published through company website, presentation at conferences, workshops, etc and through peer-reviewed international journal publications.

The work will also be promoted through the exploitation of the Digital Toolbox in the Treasure project.

By strategically leveraging the developments from the TREASURE project, MARAS B.V. aims to solidify its position as a leading provider of advanced recycling solutions, proving its impact on both national and global scale. The comprehensive integration of innovative simulation tools into their service offerings is expected to drive significant advancements in recycling technologies and sustainable practices across industries.

3.7.EDGE

Exploring the landscape of potential targets and the benefits for **KER 11** they stand to gain reveals a diverse spectrum of entities, from academic circles to large corporations, each with a unique stake in the realms of recycling, End-of-Life Vehicles (ELVs), and circular economy practices. Below, we detail the various groups that could leverage these insights to their advantage and the manifold advantages they might derive from such an understanding.

Targets

- **Research Institutions / Individuals**: Academic institutions or independent researchers interested in understanding public perceptions and behaviours related to recycling, ELVs, and circular economy practices. They could benefit from gaining insights for their own studies or projects.
- **Governments, Cities, Regions, and Municipalities**: Public authorities may seek consultancy services to better understand public perceptions and attitudes towards recycling and circular economy practices within their jurisdictions. This information can inform policy-making and initiatives aimed at promoting sustainable behaviours.
- **Large Corporations or their Departments**: Companies operating in industries related to recycling, automotive, or circular economy may find value in consultancy services to gain insights into consumer preferences, market trends, and potential areas for innovation or improvement.
- **Product and Service Design Companies**: Businesses involved in product and service design may benefit from understanding consumer attitudes and preferences towards environmentally friendly products and sustainable practices. This information can guide the development of products and services that align with market demand.
- **Companies Running Stakeholder Consultation Activities**: Organisations involved in stakeholder engagement or public consultation activities may seek consultancy services to enhance their understanding of stakeholder perspectives and concerns related to recycling and circular economy initiatives.

Benefits

- **Insight into Public Perception**: The consultancy offers insights into public perceptions and attitudes towards recycling, ELVs, and circular economy practices, helping target groups better understand consumer behaviour and preferences.
- **Informed Decision-Making**: By gaining access to valuable insights derived from digital ethnography and SSNA methodologies, target groups can make informed decisions regarding policy-making, product development, marketing strategies, and other initiatives.

- **Market Intelligence**: The consultancy provides market intelligence by analysing qualitative data and identifying emerging trends, consumer preferences, and areas for innovation within the recycling and circular economy sectors.
- **Enhanced Stakeholder Engagement**: Organisations running stakeholder consultation activities can enhance their engagement efforts by incorporating insights from public perception studies, thereby fostering more meaningful and productive dialogues with stakeholders.
- **Competitive Advantage**: Access to unique insights and data-driven analysis can provide target groups with a competitive advantage in understanding and responding to market dynamics, consumer behaviours, and regulatory changes within the recycling and circular economy domains.

We will promote our services by participating in business fairs and policy-making events with presentations and workshops, direct engagement with potential clients, participation in networking events around open calls and tenders, continuous client and partners relationship management, publication of datasets on Zenodo and preparation of related academic papers.

3.8.WALTER

The exploitation strategy of the results of the project for Walter Pack **(KER 12)** is focusing mainly on trying to share our knowledge with OEMs and show them our knowledge in order to include a product of the characteristics of the one that we are doing in the TREASURE project, in the next generation of cars. Nevertheless, the potential end users could extend to another businesses. These could include:

- **Consumer Electronics:** Manufacturers of electronic devices like smartphones, laptops, and tablets are also embracing sustainable IME. This technology allows them to create devices with reduced environmental impact by using recycled materials or bio-based plastics in the molding process.
- **Medical Devices:** The medical device industry requires components that are both functional and biocompatible. Sustainable IME can be used to create medical devices that meet these requirements while minimizing environmental impact. For instance, sustainable IME can be used to create housings for medical devices out of recycled materials.
- **Packaging Industry:** The packaging industry is another sector that can benefit from sustainable IME. Sustainable IME can be used to create environmentally friendly packaging solutions that are lightweight and biodegradable. This can help to reduce waste and promote sustainability in the supply chain.
- **Household appliances:** Touch control panels in dishwasher machines, access controls, integrated displays, … are some examples of the applications the IME could have in white goods.

In terms of the current actions in development around IME products by Walter Pack, we could mention the following:

The automotive industry, being the core business of Walter Pack, presents exciting opportunities for sustainable In-Mold Electronics (IME) solutions. Renault and Stellantis Group, both leaders in eco-friendly vehicle development, are actively promoting sustainability throughout their supply chains. Recognizing this trend, Walter Pack, along with its partner Antolin, has already introduced the IME concept to Stellantis.

Beyond automotive, the household appliance market holds significant potential for Walter Pack's IME technology. Salto Systems, a prominent player in access control systems, has expressed keen interest in replacing a traditional product with an IME solution. This demonstrates the broader applicability of IME and Walter Pack's ability to cater to diverse industries.

As fully explained in Section 1, these two examples showcase how IME products are an attractive solution for some customers concerned about sustainability and how they see significant competitive advantage over conventional electronics.

3.9.UNIZAR

As a university, UNIZAR is expected to concentrate on both research and education in its exploitation lines. Using the applied methodology and the obtained outcomes, it plans to apply for similar national or European projects based on this experience. Additionally, the results will be utilized for training courses and scientific publications. Find more details below:

- **National and European projects**: The methodology used to identify critical components in vehicles, particularly car electronics, can be applied to a broader range of industries and emerging technologies. Additionally, the new KPI developed based on thermodynamic rarity can effectively assess the sustainability and circularity of various processes and technologies. Therefore, the experience gained from this project can be valuable for future projects focused on critical raw materials.
- **Training courses**: The University of Zaragoza offers technical courses to students at various times throughout the year. Accordingly, different courses are expected to be conducted to teach the disassembly methodology applied during TREASURE, as well as the various methodologies and indicators used to evaluate circularity.
- **Scientific papers**: As a research center associated with the University of Zaragoza, the production of scientific publications is one of the department's main tasks. With the knowledge acquired during the project, new insights related to this topic are expected to be developed, leading to the publication of more articles in international journals.

4. Conclusions

The TREASURE Project allow partners to define a total number of 16 KERs (Table 1) belonging to 4 different packages (Methodological, Digital, Industrial and Standardization). KERs were developed by all the different typologies of involved partners, namely consultancy (EDGE and MARAS), academic (POLIMI, SUPSI, TNO, UNIVAQ and UNIZAR) and industrial ones (WALTER and TXT).

Developed KERs clearly show the benefits of adopting CE principles in the automotive sectors by involving all the stakeholders.

Abbreviations

AR	Augmented Reality
CE	Circular Economy
CFF	Circular Footprint Formula
CO	Closed source
COBOT	Collaborative robot
CWA	CEN Workshop Agreement
ELV	End-of-Life Vehicles
GA	Grant Agreement
IME	In-mold electronic
IP	Intellectual Property
ITO	Indium Tin Oxide
LCA	Life Cycle Assessment
KER	Key Exploitable Results
LCC	Life Cycle Costing
LCD	Liquid Crystal Display
LCS&CA	Life Cycle Sustainability and Circularity Assessment
NPV	Net Positive Value
PCB	Printed Circuit Board
PCT	Patent Cooperation Treaty
PU	Public access
S-LCA	Social Life Cycle Assessment