



TREASURE

D9.3: Follow-up activities report

31/05/2024 (M36)

Author: Paolo Rosa (POLIMI)

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.	D9.3
Dissemination level ¹	PU
Work Package	WP9
Task	T9.1
Lead beneficiary	POLIMI
Contributing beneficiary(ies)	All
Due date of deliverable	31/05/2024
Actual submission date	31/05/2024

Document history		
V	Date	Beneficiary partner(s)
V1.0	12/03/2024	POLIMI
V1.1	22/03/2024	POLIMI
VF	31/05/2024	POLIMI

DISCLAIMER OF WARRANTIES

This document has been prepared by TREASURE project partners as an account of work carried out within the framework of the EC-GA contract no 101003587. Neither Project Coordinator, nor any signatory party of TREASURE Project Consortium Agreement, nor any person acting on behalf of any of them:

- a. makes any warranty or representation whatsoever, express or implied,
 - i. with respect to the use of any information, apparatus, method, process, or similar item disclosed in this document, including merchantability and fitness for a particular purpose, or
 - ii. that such use does not infringe on or interfere with privately owned rights, including any party's intellectual property, or
 - iii. that this document is suitable to any particular user's circumstance; or
- b. assumes responsibility for any damages or other liability whatsoever (including any consequential damages, even if Project Coordinator or any representative of a signatory party of the TREASURE Project Consortium Agreement, has been advised of the possibility of such damages) resulting from your selection or use of this document

¹PU= 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)



or any information, apparatus, method, process, or similar item disclosed in this document.

EXECUTIVE SUMMARY

The report outlines the activities carried out by the TREASURE consortium that will continue also after the official end of the TREASURE project. More precisely, a summary of the standardization and patenting actions (already mentioned in D8.2 – Exploitation plan (final version) and agreement, D8.3 – IPR strategy and D8.5 – Strategic Standardization Roadmap) will be presented.



TABLE OF CONTENTS

DISCLAIMER OF WARRANTIES.....	2
EXECUTIVE SUMMARY	3
1. Introduction.....	5
2. Standardization action.....	5
3. Patenting actions.....	5
3.1. TNO’s patenting action.....	5
3.2. UNIVAQ’s patenting action	6
4. Further actions	6
4.1. POLIMI	6
4.2. TNO.....	7
4.3. UNIZAR	8
4.4. SUPSI	8
4.5. UNIVAQ.....	9
4.6. MARAS.....	9
4.7. EDGE.....	10
4.8. EUROLCDS	10
4.9. WALTER.....	10
4.10. POLLINI	11
4.11. SEAT	11
4.12. TXT.....	11
4.13. ILSSA	12
4.14. UNI.....	12
4.15. MOVEO	12
Abbreviations	13
References.....	13

1. Introduction

The aim of this document is reporting a list of follow-up activities that will continue also after the official end of the TREASURE project (set of 31st of May 2024) in disseminating and exploiting the results achieved in TREASURE by the different partners. These activities are mainly distinguished in i) a standardization action willing to open the way to a new standard in terms of Critical Raw Materials (CRMs) recovery procedures from car electronic components, ii) two patenting actions related to both In-Mold Electronics (IME) sustainable disassembly and design (activated by TNO) and In and Ag hydrometallurgical recovery processes from ITO glasses and IME (activated by UNIVAQ) and iii) further actions followed by each partner in order to continue with the valorization of the TREASURE results after the end of the project.

2. Standardization action

This section summarizes the CEN Workshop Agreement (CWA) post-publication procedure (already presented in D8.5 by UNI). Within the TREASURE project it has been developed the CWA “A methodology to improve the recyclability rate of Strategic/Critical Metals from car electronics”. A CWA is a consensus-based document produced through a CEN Workshop. Unlike formal standards, CWAs are developed more rapidly and involve direct participation from stakeholders who are interested in or affected by the subject matter. It serves as a flexible and efficient tool for documenting and disseminating best practices, technical specifications, or procedural guidelines, addressing the immediate needs of the market while paving the way for future formal standardization efforts. After a CWA is published, its journey continues in several meaningful ways, reflecting its unique role in the standardization landscape. After its publication, a CEN Workshop Agreement is disseminated for immediate use, providing valuable guidelines and solutions to the industry. Its adoption and feedback can pave the way for developing formal standards, ensuring that the CWA's initial insights continue to benefit broader standardization efforts. Periodic reviews ensure its ongoing relevance and alignment with industry needs and technological advancements. All the TREASURE consortium has been involved during the development of the CWA.

3. Patenting actions

This section reports the ongoing patenting actions activated by TNO and UNIVAQ (also mentioned in D8.2 and D8.3).

3.1. TNO's patenting action

TNO at Holst Centre explored a disassembly method in EU TREASURE that was invented prior to the start of the project. As part of the patenting procedure, an evaluation was made of the prior art and after finding that our idea had not yet been published, was novel and inventive, the idea was filed, resulting in WO2022220688.

During the EU TREASURE project, TNO had to first establish an industrial way of working for injection molded devices. Before TREASURE, the TNO approach to in-mold electronics (IME) focused on thermoforming with occasional injection molding by third parties to complete a prototype device. On lab-scale, TNO worked with flooding the electronics with epoxy resin, rather than injecting hot polymer onto a functional substrate which is typical of the industrial process. EU TREASURE provided TNO the opportunity to explore the concept of disassembling IME, but also to come closer to an industrial process. Surprisingly, the TNO's proposed methods and materials proved quite effective and issues that were encountered during the project had been included in the original document. As a result, no additional IP filings were required.

Regarding recycling of plastics, the TNO team on that topic was involved after roughly 1.5 years. TNO could make use of its patented methods to recycle the plastics in IME and formulate a realistic end-of-life scenario for this kind of electronics. The TNO's lab devices were readily recycled with their approach. TNO had the opportunity to investigate what happens to materials other than the bulk plastics in the IME devices during the plastics recycling process. This research has not yet been fully completed, but TNO has found that also the metals and semiconductor components can be retrieved by means of filtering. No new IP could be generated at this point; TNO made use of the patented method.

3.2. UNIVAQ's patenting action

UNIVAQ, as part of the EU TREASURE project, has developed hydrometallurgical processes to recycle strategic materials in the automotive sector. These processes aim to recover base and precious metals from PCBs of car dashboards, extract silver from IME, and recover indium from ITO glass of LCDs.

It is important to note that UNIVAQ already owned two patents for the hydrometallurgical recycling of PCBs before the EU TREASURE project began. The first patent, named Gold-REC 1 [1], focused on treating a powder of PCBs, while the second patent, named Gold-REC 2 [2], aimed to recycle gold and other metals in SMDs of boards with a high gold concentration on the surface, such as gold-plated components.

During the EU TREASURE project, UNIVAQ found that it was necessary to disassemble specific SMDs from the board before extracting metals to increase yields. As a result, two hydrometallurgical routes were implemented, building upon the pre-existing patents. Through lab and pilot-scale activities, UNIVAQ optimized the two patents using an MLD approach to reduce wastewater production by recycling solutions and saving chemicals. Additionally, a specific wastewater treatment section was included in the process to reduce costs and obtain treated water with quality characteristics suitable for reuse in the next batches.

As a result of these investigations, the two patents are now more robust, reliable, and ready to be commercialized, even in the automotive sector.

Regarding the recycling of silver from IME and the recycling of indium from ITO glass, the developed processes were studied at a lab scale and validated by performing tests on the reconfigured hydrometallurgical pilot plant. The results showed that the processes are both economically and environmentally sustainable. Innovative aspects related to the regeneration of some chemicals during certain operations of the processes enabled the saving of chemicals and, therefore, reduced operating expenses. MLD approach has been adopted by including specific wastewater treatment sections that allowed to minimize the use of freshwater in the hydrometallurgical processes. Also considering the perspective of the silver and indium markets, UNIVAQ proposed a new patent.

4. Further actions

In the following sections the further actions are described for each partner.

4.1. POLIMI

4.1.1. Follow-up projects

POLIMI will exploit both the knowledge on automotive Circular Business Models (CBMs) and semi-automated Printed Circuit Boards (PCBs) disassembly processes developed in TREASURE in another ongoing Horizon project named CIRC-UIITS (coordinated by POLIMI). Within CIRC-UIITS, the same semi-automated PCB disassembly process configuration will be adopted in order to

safely desolder valuable semiconductors from the main boards so to guaranteeing their reusability in new applications. This would really enable the circularity of PCBs in some reference sectors as mass and car electronics.

4.1.2. Follow-up events

POLIMI will continue the dissemination of the TREASURE results also after the end of the project. The pilot implemented in TREASURE will be presented in international conferences as, EGG (Jun 2024), IARC (Jun 2024), ICE/ITMC (Jun 2024), PLM (Jul 2024), APMS (Sep 2024). All these events will take place after TREASURE project ends.

4.1.3. Follow-up publications

A set of publications related with the results achieved in TREASURE will be developed within the end of 2024. These publications will mainly focus on:

- Semi-automated PCB disassembly procedures
- Human-robot interaction
- Criticality of materials embedded in PCBs
- Circular Business Models for car electronics
- Digital tools supporting circularity performances
- Sustainability & circularity performance indicators

4.2. TNO

4.2.1. Follow-up projects

Within the EU TREASURE project, TNO is unable to continue towards a higher TRL concept and take next steps for recycling of in-mold electronics. TNO did manage to embed the topic into other projects, including EU UNICORN (coordinated by VDI/VDE Innovation + Technik GmbH) and EU CIRC-UIITS (coordinated by POLIMI). The first project addresses a similar dismantling approach, but using reversible adhesives, rather than TREASURE's water-based non-adhesive. Such materials needed to be synthesized and could, as such, not be included into EU TREASURE easily. EU CIRC-UIITS deals with an alternative end-of-life scenario that focuses on extending the lifetime by repairing. This could be relevant for production failures and potentially for broken electronics during the use phase, although the first seems more applicable. When proposing this challenging topic in EU CIRC-UIITS, it felt extremely ambitious to attempt this. Experiences with EU TREASURE gave confidence that we could make and dismantle in-mold electronics, but repairing and re-molding parts needed more research. The approach is very novel and is still being investigated at Holst Centre within the CIRC-UIITS project scope. Because the same methodology and materials were needed to dismantle, no new IP was required.

4.2.2. Follow-up events

Holst Centre will disseminate sustainable developments for printed electronics in general and in-mold electronics specifically at regular intervals. Regular events including IMSE days (June 2024), Holst Centre's Innovation Day (June 2024) and TechBlick (Oct 2024) have been expanded with AMI chemical recycling (June 2024) and possibly also with Automotive Interior Expo (Nov 2024). All these events will take place after TREASURE project ends.

4.2.3. Follow-up publications

After an initial publication on disassembly of printed electronics in Journal of Cleaner Productions, that needed to wait for full publishing of the patent, TNO will continue with additional manuscripts focused on:

- Recycling of in-mold electronics
- Life cycle assessment of in-mold electronics
- Repair of in-mold electronics (TREASURE methodology combined with repairing in EU CIRC-UIITS)

TNO hopes to realize these publications within the TREASURE project, but the timing is challenging. In case TNO will not succeed in the short time that remains for TREASURE project, they will continue in the months hereafter.

4.3. UNIZAR

4.3.1. Follow-up projects

UNIZAR will exploit the knowledge gained from TREASURE project through several national projects, already funded, focused on the vehicle. Particularly, the RELOAD project and the ECLIPSE project, which are described below. The RELOAD project (1/7/2022 -30/6/2025) aims to contribute efficiently and safely to the supply of high-value metals in the Electric and Connected Vehicle (ECV) industrial value chain, reducing dependence on imports and promoting a sustainable, circular industrial model with a lower environmental footprint. To achieve this, different recycling technologies, eco-design, and Industry 4.0 will be researched. In this respect, UNIZAR will apply the thermodynamic rarity methodology to assess the criticality of specific key parts of electric vehicles, including the battery or the charger and carry out disassemblability assessments that will be automatized by a robot. The ECLIPSE project (28/12/2021 - 31/12/2024) focuses on researching innovative technological pathways for recycling and valorizing complex polymeric waste, aiming for a disruptive advancement over the state of the art in terms of separation, recycling, purification, and chemical synthesis of building blocks. These advancements enable the production of high-quality recycled polymers, offering an alternative to mechanical recycling wherever it is needed. UNIZAR has adapted the thermodynamic rarity methodology applied within TREASURE, to the criticality and recyclability assessment of plastic car parts.

4.3.2. Follow-up events

UNIZAR will continue to disseminate the knowledge gained during the project even after its completion. The thermodynamic rarity assessment conducted on vehicles components, as well as the disassemblability procedure of the most critical, are expected to be presented at international conferences such as ECOS (Greece 2024) and CPOTE (Poland 2024), which will take place after the conclusion of the TREASURE project.

4.3.3. Follow-up publications

Some publications are expected under the framework of TREASURE project and the results obtained throughout the activities carried out, focusing on:

- Thermodynamic rarity analysis of a vehicle.
- Critical components in a vehicle.
- Criticality of materials embedded in a vehicle
- Sustainability and circularity of vehicles

4.4. SUPSI

4.4.1. Follow-up projects

SUPSI will exploit both the knowledge on sustainability and circularity assessment and advisory methods, KPIs and the GRETA tool developed in TREASURE in other ongoing Horizon projects named CIRC-UIITS, CIRCULOOS, SILKROP, DACAPO, DENIM, CIRCTHREAD, AMBIANCE.

4.4.2. Follow-up events

SUPSI will continue the dissemination of the TREASURE results also after the end of the project, presenting the Sustainability and Circularity Advisory, both Methodology and Tool, in the international conference Electronics Goes Green (June 2024). Moreover, SUPSI will host a half-day event in October 2024 dedicated to Circular Economy. The event will be organized in the context of CircThread project (Horizon 2020).

4.4.3. Follow-up publications

SUPSI will continue with additional manuscripts focused on:

- The development of GRETA tool (architecture, functionalities, case studies).
- The LCA of the in-molds electronics (in collaboration with TNO).

4.5. UNIVAQ

4.5.1. Follow-up projects

UNIVAQ plans to utilize the knowledge and patent obtained from the TREASURE project, which involved developing hydrometallurgical recycling processes for indium and silver from ITO glass and IME respectively, in future projects. The recycling technology studied for silver from IME could also be applied to the recycling of photovoltaic panels. This process can be immediately commercialized in the photovoltaic industry, given the high availability of end-of-life photovoltaic materials. Additionally, the mobile hydrometallurgical pilot plant (TRL5), which was reconfigured during the EU TREASURE project, can now be used to recycle various materials. Therefore, it remains an important milestone for investigating other recycling processes on a pilot scale allowing the end users to obtain reliable results. UNIVAQ is using its knowledge in the ambit of many ongoing EU projects such as PEACOC, NEW-RE, INSPIREE, WEEKO and GRAPHIREC.

4.5.2. Follow-up events

UNIVAQ will continue to disseminate the results after the end of the project, presenting the advances in hydrometallurgical recycling in the automotive sector by also focusing on the validation tests performed at the pilot scale. Specifically, UNIVAQ will present part of the activities on the following congress: CISAP11 – Naples 18-09-2024, “Chemical and process risk management in the operation of the Treasure pilot plant for the treatment of e-waste by hydrometallurgical processes”.

4.5.3. Follow-up publications

UNIVAQ plans to publish papers on the recycling of PCBs, IME, and ITO glass of LCDs, including their wastewater treatment sections. One paper, in collaboration with POLIMI, will discuss the disassembly benefits of removing SMDs from the board to increase metal recycling rates. Another paper will focus on hydrometallurgical routes for PCBs recycling. Then, after the patent filing date, several papers will be published on the selective recycling of indium from ITO glass and on the recycling of silver from IME, including one in partnership with TNO and MARAS.

4.6. MARAS

4.6.1. Follow-up projects

MARAS will exploit both the knowledge on sustainability and circularity assessment and advisory methods, KPIs and the simulation tool developed in TREASURE in another ongoing Horizon project named CIRC-UIITS. MARAS is developing a report for the JRC in Ispra (Directorate General Sustainability EC), that will highlight for example the importance of having simulation-based i.e. physics-based analysis of supply chains as also applied within the TREASURE (and other) project(s) in order to be able to understand the physics limits of supply chains, set-up recycling

KPIs, assess CE and link to LCA methodologies. MARAS is involved in the submission of a project focused on durable IMEs together with TNO (project leader). MARAS will continue the work as started within the TREASURE project on EoL assessment and EoL LCA for IMEs.

4.6.2. Follow-up events

No specific events have been planned yet, however MARAS (and members) will be involved in training and education of MSc and PhD students. MARAS will continue to present the work on recycling modelling, sustainability & circularity assessment, KPI definition and calculation and CE assessment and LCA in various events in future.

4.6.3. Follow-up publications

MARAS will publish the work on recycling simulation and S&C assessment and advisory in close future (just after finishing of TREASURE project) and any follow up on this in peer-reviewed journals. A publication is planned and drafted together with UNIZAR. Various publications are planned together with TNO and UNIVAQ on (the recycling of) IMEs.

4.7. EDGE

4.7.1. Follow-up projects

EDGE will exploit the knowledge acquired through its research during the TREASURE project for consultancy projects, with possible participation of other partners. We will continue to fine tune our data collection methods and continue to develop our ethnographic tool. In particular, we will work on higher integration of OpenEthnographer with external open source visualisation tools such as Tulip.

4.7.2. Follow-up events

No events have been planned yet, but EDGE will continue to present the ethnographic mapping of segments of the circular economy.

4.7.3. Follow-up publications

EDGE is preparing a publication documenting our research during the project, which will include the salient moments of the community journalism program, such as interviews, articles, stories and artwork. The publication will support our consultancy exploitable route presented. Shortly after the end of the project we will submit the second iteration of the paper on TREASURE for the Journal of Industrial Ecology.

4.8. EUROLCDS

No follow up activities are expected.

4.9. WALTER

4.9.1. Follow-up projects

Thanks to the TREASURE project, a new line of work on In Mold Electronics (IME) has been opened for WALTER. Which focuses on the eco-design of this already novel technology, and which is still under development. Building upon our IME expertise, WALTER is forging ahead with new development projects. Our focus is on creating an industrially viable IME solution for our main customers. Therefore, WALTER will continue to develop projects around IME technology with higher TRLs in order to offer them to customers with guarantees, both in the automotive and home appliance sectors. In addition, we will integrate the concept of sustainability into them, being able to exploit the dismantling layer developed by TNO in some type of future collaboration.

4.9.2. Follow-up events

WALTER will focus on disseminating IME technology at the customer's premises. We will do this through online or in-person tech days, with the aim of industrializing products with IME technology. In addition, some attendance to shows will be valuable such as the Automotive Interior Expo (Nov 2024) and the LOPEC (Feb 2025) focused on Printed Electronics.

4.10. POLLINI

4.10.1. Follow-up projects

POLLINI will exploit the knowledge on semi-automated PCB disassembly processes developed in TREASURE in another ongoing Horizon project named CIRC-UIITS.

4.10.2. Follow-up events

No follow-up events are expected.

4.11. SEAT

4.11.1. Follow-up projects

SEAT will exploit the knowledge gained from TREASURE project through several national projects, already funded, focused on the car. Particularly, the RELOAD project and the ECLIPSE project, which are described below. The RELOAD project (1/7/2022 -30/6/2025) aims to contribute efficiently and safely to the supply of high-value metals in the Electric and Connected Vehicle (ECV) industrial value chain, reducing dependence on imports and promoting a sustainable, circular industrial model with a lower environmental footprint. To achieve this, different recycling technologies, eco-design, and Industry 4.0 will be researched. The ECLIPSE project (28/12/2021 - 31/12/2024) focuses on researching innovative technological pathways for recycling and valorizing complex polymeric waste, aiming for a disruptive advancement over the state of the art in terms of separation, recycling, purification, and chemical synthesis of building blocks. These advancements enable the production of high-quality recycled polymers, offering an alternative to mechanical recycling wherever it is needed.

4.11.2. Follow-up events

SEAT, in collaboration with UNIZAR, will continue to disseminate the knowledge gained during the project even after its completion. The thermodynamic rarity assessment conducted on car components, as well as the disassemblability procedure of the most critical, are expected to be presented at international conferences such as ECOS (Greece 2024) and CPOTE (Poland 2024), which will take place after the conclusion of the TREASURE project.

4.11.3. Follow-up publications

Some publications are expected under the framework of TREASURE project in collaboration with UNIZAR and the results obtained throughout the activities carried out, focusing on:

- Thermodynamic rarity analysis of a car
- Critical components in a car
- Criticality of materials embedded in a car
- Sustainability and circularity of cars

4.12. TXT

4.12.1. Follow-up projects

TXT will exploit both the knowledge behind the TREASURE platform and the IT infrastructure itself developed in TREASURE in other ongoing Horizon projects named CIRC-UIITS and DACAPO.

4.12.2. Follow-up events

No follow-up events are expected.

4.13. ILSSA

4.13.1. Follow-up projects

ILSSA will keep working on exploiting the knowledge on sustainability and circularity assessment, recyclability methods, KPIs and the simulation tool developed within the TREASURE Project. ILSSA will keep working on how to recycle the different materials and waste arriving at its facilities related to automotive industry, e-waste and ferrous and non-ferrous wastes.

4.13.2. Follow-up events.

ILSSA will keep participating in different events related with automotive industry, disassembly, waste and recyclability of the different waste that are treated in our facilities. An attempt will be made to participate in local, regional, national and international events related to the recycling industry.

4.14. UNI

4.14.1. Follow-up projects

UNI will keep working on exploiting the CWA, the pre-standardization document “A methodology to improve the recyclability rate of Strategic/Critical Metals from car electronics” developed within Treasure project and based on the project view and results. In particular, UNI will follow the activities related to the CWA till its publication on [CEN/CENELEC website](#). After its publication, as UNI has done for other research projects it was involved in (i.e. RECLAIM project, with the CWA 18038:2023 “Methodology for managing maintenance strategy and remanufacturing projects of large industrial equipment”), it will be explored the possibility to adopt at Italian level the pre-standardization document, so to push its implementation by the market at national level.

4.14.2. Follow-up events

UNI will present the Treasure CWA to its internal strategic steering committee during its next meeting (foreseen for the second semester in 2024), to increase the awareness towards the results of the project. Moreover, UNI is exploring the possibility to have a follow-up of the CWA by participating to further EU projects.

4.15. MOVEO

4.15.1. Follow-up projects

MOVEO will continue to promote the circular economy and the TREASURE solutions and partices even after the end of the project. Based on TREASURE learnings, MOVEO has defined a specific roadmap on circular economy with the following objectives: 1) Generate and accompany EC projects within MOVEO eco-system, 2) Provide acculturation on EC principles to partners to incite them to create profitable business models more sustainable and encouraged them to limit their consumption of critical raw material and waste creation by using dedicated tools and methods as the ones proposed within the TREASURE project. These activities are planned till end of 2026 and will be accompanied by specific events.

4.15.2. Follow-up events

Some activities and events are planned in the specific EC MOVEO roadmap and new ones will planned in the future till the end of this transversal project. First parts of the activity will be concentrated on the eco-system. Identification of the EC principles early adopters, competencies

of our partners to propose EC solutions and especially the needs of our eco-system partners. The maturity and the strategic EC pillars are really different for one company to another. This first phase will allow us to structure our event animation of the second phase. In the list of events we will use to promote EC principles and present TREASURE solutions, we will mainly include: webinars, round table and conference, workshop and a club dedicated to circular economy.

Abbreviations

CBM	Circular Business Model
CRM	Critical Raw Material
CWA	CEN Workshop Agreement
EU	European Union
IME	In-Mold Electronics
IMSE	In-Mold Structural Electronics
IT	Information Technology
ITO	Indium-Thin Oxide
KPI	Key Performance Indicator
PCB	Printed Circuit Board

References

- [1] WO2018215967A1 Process for the hydrometallurgical treatment of electronic boards, Inventors: I. Birloaga, F. Vegliò, I. De Michelis, F. Ferella, May 2018, Priority number - IT201700057739A·2017-05-26 (**Gold-REC 1**).
- [2] WO2019229632A1, Hydrometallurgical method for the recovery of base metals and precious metals from a waste material, Inventors I. Birloaga, F. Vegliò, December 2019, Priority number - IT201800005826A·2018-05-29 (**Gold-REC 2**)