D4.9: Platform Circular (AI-based) advisory module (1st version)

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EXECUTIVE SUMMARY

The present deliverable is the first document released within T4.5 "Circular (AI-based) advisory tool" describing the first version of the Advisory platform starting from the methodology explained in D2.2 "Sustainability advisory methodology definition". Thus, the document accompanies the preliminary software release of the sustainability advisory tool which will be further developed and refined in the following months until M33 when the final version will be implemented and depicted in D4.10 "Platform Circular (AI-based) advisory module (final version)".

This preliminary tool implementation has been designed in accordance with the TREASURE technical architecture presented in D4.1 following the same layout used for the Circularity Web Platform which is described in D4.7. This aspect is mainly visible in the graphic interface style and it's due to the fact that the user can access not only the AI-based Advisory tool but also the Disassemblability, Recyclability and Eco-Design Web Platform since for each platform module there is a link to the advisory section. The main purpose of the advisory tool based on artificial intelligence is to provide support to decision-makers in the different decision-making moments that occur in the use cases of disassembly, recycling and eco-design. Decisions are supported considering the environmental, economic, social and circular aspects related to each decision. Thus, the tool has been designed to provide data in a clear and user-friendly approach, mainly based on tables and chart, to maximize the user experience.

The Circular AI-based advisory tool comprises three modules, similarly to the Circularity Web Platform:

- Disassemblability AI-based Advisory Module: provides a ranking of critical components to be extracted from a selected car, presenting the most convenient disassembly path to follow.
- Recyclability AI-based Advisory Module: provides a ranking of most convenient recyclability routes starting from the analysis performed by the Recycling Simulation Tool and further complemented by a socio-economic impact assessment.
- Eco-design AI-based Advisory Module: focused on two processes: re-design of a product already analysed by the platform and design of a new product. The re-design is performed by examining the compliance level of the existing design, proposing improvements and comparing the existing design with the improved one, based on a set of indicators.
  Instead, the new design is performed by showing the eco-design guidelines to provide guidance to the designer. After the realization of a preliminary design of the new product, improvements are proposed and an evaluation of compliance with the guidelines is performed.

These three applications are strongly connected to the project main modules, starting from the results of the analysis performed in T3.2, 3.3 and 3.4, the indicators used to assess the most suitable disassembly and recycling procedures and the reference framework on which TREASURE platform is based. For this reason, the Circular AI-based Advisory Tool will be further developed in the following months taking into consideration not only the user validation results coming from testing activities but also the technical enhancement that the three modules of the Circularity Web Platform will undergo.

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1 Introduction

Deliverable D4.9 starts from the outcomes and considerations achieved from the analysis performed in T2.2 concerning the sustainability advisory methodology definition reported in D2.2. For this reason, the first sub-chapter summarizes the reference framework on which the tool design and implantation is based. The second section of the first chapter is assigned to present an overview of the Circularity AI-based Advisory application, specifying its position and dependencies with other platform components while outlining the scope of each advisory module.

The chapter two is the document core since it describes in depth the tool features and user functionalities of each module. For the three applications, a detailed explanation is provided concerning the structure of the platform dashboard, which is split in different sections, and the type of data displayed. More in detail, the first chapter focuses on the Disassemblability AI-based Advisory Module depicting the overall scope and its part: the disassembly route section, assigned to illustrate step by step the necessary operations to perform to dismantle the selected car part; the estimated revenue section, with indication of the key elements from an environmental and economic point of view; and the feedback section, where the user can note comments. The following sub-chapter provides information about the Recyclability AI-based Advisory Module that comprises a ranking of the suggested routes for the selected car component based on the Recycling Simulation tool analysis. The module sections are: the disassembly and recycling route advisor, displaying the list of proposed recycling path with an overview of the major impact analysis performed within the project scope; the route integration chart that shows a graphical representation of the impact studied presented in the previous section; and the feedback section, where the user can note comments. Finally, the Eco-design AI-based advisory module is depicted, providing to car manufacturers useful information to identify the most suitable car design according to specific KPIs. The described sections are: the old design, displaying the 2D image of the selected car part with the key issues related to the disassembly and recycling process based on the feedbacks gathered from dismantlers and recyclers; the new design, focused on the evaluation of the improved design compliance to determined guideline groups; and the old vs new design comparison section, assigned to analyse the existing and improved design based on the thermodynamic rarity indicator in connection with the aforementioned guideline groups.

Finally, the conclusions and future steps for the refinement of modules implementation and integration close the chapter.

1.1 Project Overview

TREASURE – *"leading the TRansition of the European Automotive SUpply chain towards a circulaR futurE"* wants to support the transition of the automotive sector towards Circular Economy (CE), by providing a concrete demonstration of how the industry can benefit from the adoption of Circular Economy practices and principles, both from a business and a technological perspective. One of the main encountered issues highlighted by the automotive actors, refers to the huge information gap existent between Beginning-of-Life (BoL) and End-of-Life (EoL) actors along the whole automotive value chain up to the final consumers.

TREASURE aims at filling this gap through the development of an AI-based assessment tool able to connect and facilitate the interaction among the key involved stakeholders dedicated to car electronics: car parts suppliers, car makers, dismantlers, and shredders. On the other hand, TREASURE goal consists in assisting both BoL and EoL actors in performing their operations, (best recycling options for optimal recovery), taking the most suitable decision according to up-to-date information, as well as in assessing the impact and the effect of their decision on the final customers.

To this aim, a web-based platform will be developed as a new information sharing tool among all stakeholders, both in forward and backward directions, ensuring secure access and confidentiality. The platform will indeed be developed in order to enhance the connection among the actors, making information available through specific modules that will be built and tailored according to their needs.

The platform will be tested with a set of dedicated demonstration actions within the project boundaries. However, it will be designed assuring that its potential can go beyond the project and its sustainability will be properly defined and agreed with the TREASURE consortium, guaranteeing the possibility for its scale-up and adoption by a wider group of stakeholders.

1.2 Scope of the deliverable

Since this document presents the first version of the Circularity AI-based Advisory Tool, a full description of activities carried out in this task is presented starting from the application design, based on the methodology defined in D2.2, and leading to the application development in its preliminary version. Since a continuous iteration and validation process is foreseen, the Circularity AI-based Advisory Tool structure will be refined in the following months in order to establish the final version which will be fully described in D4.10, due on M33.

1.3 Contribution to other WPs

Given the fact that the present document is the first step of the implementation of the T4.5 “Circularity AI-based advisory tool”, it’s evident that the activities carried out in this task are strongly connected not only with T2.1 and T2.2 but also with T4.1, T4.2 and T4.4. The analysis and state of the art study performed in the first task group laid the foundation of the application design and input/output data flow. As for the WP4 activities, the user requirements defined in T4.1 affected the Advisory Tool design since the same framework and GUI of the Circularity Web Platform has been used. Moreover, the Data Lake development partially included also the Advisory tool, as reported in chapter 2.2 assigned to architecture description. This approach also applies for activities carried out in T4.4 since the AI-based Advisory Tool is strongly connected to the Circularity Web Platform, based on the analysis of both the disassembly and recycling procedure determined in T3.2 and T3.3. Moreover, the study of eco-design, disassembly and recycling guidelines and integration with CE indicators had a pivotal role in defining the eco-design advisory module. In fact, as it is fully described in chapter 3.3, the data provided in this application concerns not only operator’s feedbacks on disassembly and recycling procedure, partially collected within T3.2 and T3.3, but also the state-of-the-art analysis carried out in T3.4. The data input also regards the indicators developed in WP2 to be integrated in the tool to perform the analysis required for assessing the new design improvements. The work performed in T4.5 will also play a role in the technical execution of WP5 activities related to platform application, testing and validation in selected uses cases. The TREASURE Platform will then be assessed in the demonstration phase performed within WP6, evaluating the new procedure performances in terms of circularity and economic feasibility. Like the Circularity Web Platform, technical validation and verification of the Advisory Tool will be executed in Task 4.6.

2 Sustainability and Circularity AI-based Advisory Tool Overview

The Sustainability and Circularity AI-based Advisory Tool has been designed starting from the state-of-the-art analysis on methodologies and tools able to provide Life Cycle Sustainability & Circularity Advisory (LCS&CAd), and on how AI is exploited to improve sustainability and circularity performance of processes by providing decision-making support. In relation to the results from the state-of-the-art analysis, from workshops made with the pilots and together with the results obtained in T2.1, T3.1, T3.2, T3.3, T4.1, the Sustainability and Circularity Advisory methodology was created. The study performed in D2.2 lays the foundation of the advisory methodology definition described in the same deliverable and summarized in the following chapter for the scope of the present document. The inputs coming from D2.2 represent the pillar for the tool implementation and subsequent revision according to user testing that will peak starting from M18 and continue till M33 when the final version of this deliverable (D4.10) will be released.

2.1 Methodological Approach

The methodology followed for the design and implementation of the Sustainability and Circularity AI-based Advisory Tool is fully described in D2.2 that provides an extensive depiction of the application purpose and scope. The starting point to define the tool is the state-of-the-art analysis performed to gain knowledge of current status of technologies (AI-based and not) supporting the disassembler, recycler and the designer in integrating sustainability and circularity in their activities. Specifically, helping them in decision-making phase, providing metrics and indication of best practices. In addition to this study, three workshops have been organized during the project first year to map the AS IS scenario of each use case in order to identify critical issues, processes, and decisions to be supported. The following step consisted in correlating the AS-IS situation analysis with the workshops outcomes with the aim at extracting the sector decision rules used, to align the advisory tool with the decision drivers of the industry, assessing the information flows to and from the platform. This work led to design preliminary conceptual advisory ideas that have been discussed with stakeholders collecting relevant feedback to define the links and correlations between the various use cases to expand the platform suitability for several user needs.

From the methodological point of view, initially, a state-of-the-art study of strategies, methodologies, and tools to support end-of-life (EoL) product decisions in electronics disassembly and recycling use cases and to support early life (BoL) decisions in electronics eco-design use cases has been performed. The SoA study found room for improvement for current EoL advisory strategies and highlighted the absence in the literature of an advisory methodology that integrates circularity and sustainability to support eco-design decisions. The already cited workshops with use cases then served to gather information on the decision-making processes currently in use at the pilots and to outline future processes to be adopted, which consider the use of Key Enable Technologies (KETs) and possible advisory functions. The results of the workshops were used as a starting point for subsequent activities to propose an advisory methodology. The sustainability and circularity advisory framework described in D2.2 presents the decision-making processes of the three use cases and highlights the decisions that can be supported by the advisory service. In this proposal, the use cases of disassembly and recycling were treated together, as a high interdependence between the two was found. For the use case of eco-design, a greater need for advisory services was found and two decision lines were developed, one featuring redesign and another featuring new design. An initial proposal to integrate the advisory tool with the rest of the TREASURE platform has been also investigated. Dashboard proposals, in relation to the three modules of the platform, were sketched out considering different users of the advisory service in the role of decision-makers. Moreover, the future development and refinement of the Sustainability and Circularity AI-based Advisory Tool will need further interaction with pilots partners to better focus on the environmental, economic, social and circular topics considered as more interesting and to actually determine the data sources and calculation possibilities. For this reason, a survey methodology to identify with future users of the advisory service, the indicators to be selected has been designed. The survey aimed to provide a method to be used in subsequent project activities to select KPIs and indicators and to investigate aggregation needs.

2.2 Architecture Overview

The Circularity AI-based Advisory Tool works on top of TREASURE platform, playing the role of sustainability enabling technology to support designers in the decision-making process with the aim at identifying the most circular path for car disassembly, recycling and design operations. As shown in the figure below, the application ingests data coming from internal sources, provided by the Data Lake that, in return, draws information from external provenance, such as the MISS Database. Moreover, some input data originate from the study performed in D2.2 comparing the state-of-the-art analysis with the feedbacks coming from operators. This is particularly relevant for the identification of eco-design guidelines that are based on an evaluation process of dismantler and recycler comments regarding procedures applied to selected car parts. The operator feedbacks are essential to assess the most sustainable routes and manufacturing design in correlation with the academic knowledge acquired from best practices and EU CE directives in the automotive and WEEE/EEE sector.

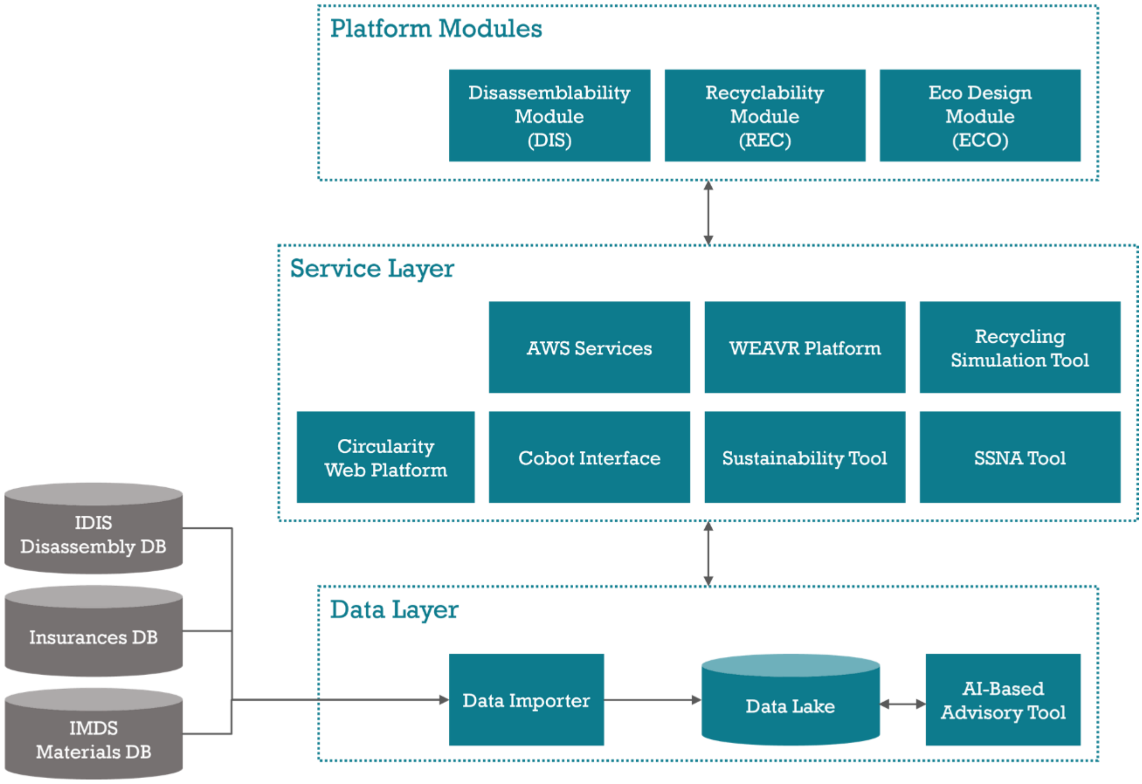


Figure 1 Circularity AI-based Advisory Tool in TREASURE Architecture

Since the Circularity AI-based Advisory Tool has a comprehensive function connected to all Circularity Web Platform areas (Disassemblability, Recyclability and Eco-Design), the application foresees 3 sections corresponding to each module. The three modules that are part of the core platform are depicted in the upper part of Figure 1 while the Sustainability and Circularity AI-based Advisory Tool is presented inside the data layer section. For each module, the Advisory application provides specific information according to the analysis that the designer has to perform, the tools used and the results foreseen. It's paramount to note that the Circularity AI-based Advisory tool is part of the TREASURE application, yet, unlike the three core modules, it is connected to all platform sections. Thus, the user can access not only the AI-based Advisory tool but also the Disassemblability, Recyclability and Eco-Design Web Platform since for each platform module there is a link to the advisory section.

To ensure clarity and avoid confusion, for the scope of the present document, a clarification on naming is here proposed: the Disassemblability, Recyclability and Eco-Design modules refer to the building blocks that are the pillars of TREASURE platform, the Circularity Web Platform, described in D4.7 and part of T4.1, T4.2 and T4.4 activities; while the Disassemblability, Recyclability and Eco-Design Advisory modules consist in the AI-based applications providing sustainability/circularity recommendation for decision makers/designers, defined in the present deliverable based on activities carried out in T4.5.

More in detail, the Advisory Tool is split in the following sub-applications:

- Disassemblability AI-based Advisory Module: provides a ranking of critical components to be extracted from a selected car part presenting the most convenient disassembly path to follow. The hierarchy of the results shown in the Advisory tool are based on specific KPIs coming both from the analysis carried out for the methodology definition

in D2.2 and the dismantler feedbacks collected via the disassemblability module in TREASURE platform. The metrics include information related to:
  - the disassembly process: operation time, cost (actualized for specific hourly/rate), difficulty level (assessed according to selected indicators), required tool to complete the dismantling;
  - The car component composition: material mass, recovery rate, thermodynamic rarity and market value of the removed part/s
- Recyclability AI-based Advisory Module: provides a ranking of most convenient recyclability routes starting from the analysis performed by the Recycling Simulation Tool and further complemented by a socio-economic impact assessment. Like the previous advisory module, a section for feedbacks collection is foreseen.
- Eco-design AI-based Advisory Module: defines the compliance level of the existing and improved design with specific guidelines using a radar graphic that highlights key impact factors according to user preferences. This section presents a comprehensive analysis of the best improvements to implement based on the previous modules input/output data and feedbacks.

The three advisory modules are fully described in the following chapter with a detailed explanation of how each section has been designed and the information representing.

3 Circularity AI-based Advisory Tool Implementation

Starting from the architecture design exposed in the previous chapter, the Circularity AI-based Advisory Tool has been developed following the same methodology used for the other platform module implementation. Firstly, the user requirements and project final goals have been taken into consideration to define the key elements to include in the platform structure, specifying the data flow with clear identification of inputs/outputs and sources/results. After this preliminary step, the work was focused on determining the most suitable graphic interface that comprises all relevant information in a user-friendly and intuitive approach in order to make the application ready-to-use with less training as possible. It’s been applied the same GUI style already used for the core modules of the Circularity Web Platform which is described in D4.7: in the upper part the username and role is displayed together with the search bar to find the car part that is the object of the study. By selecting the component to analyse, the dashboard shows the information and analysis results related to the specific module in table or chart form depending on the data set.

Regarding the Circularity AI-based Advisory Tool authorization protocol, only one type of user is foreseen with the right to both visualize all information and edit some tables. For the time being, the user must register to the platform and be approved by the administrator, but no other authorization is required to access all three advisory modules or a specific section. Thus, once the user role is granted, the designer/consultant can browse the whole platform, skipping from one application to one at any time. This functionality can be modified changing the authorization rights according to emerging needs with the option to grant access to one or two modules only.

It must be noted that, in alignment with the Circularity Web Platform, this preliminary version of the AI-based Advisory Tool has been implemented taking into consideration as a reference example one car part only as a pilot case. The selected car component is the Combination meter of SEAT Leon II that has been chosen due to its complexity since it’s made of different sub-parts. For each of the advisory modules, a complete description of functionalities is provided in the following chapters with a detailed explanation of how the dashboard is split in different sections and the type of data displayed.

3.1 Disassemblability AI-based Advisory Module

The Disassemblability Advisory module provides information concerning the best dismantling routes from a sustainability and recovery perspective, highlighting the key indicators relevant for the assessment of the proposed disassembly path. In the figure below the full dashboard in its preliminary version is presented while in the following chapters (3.1.1., 3.1.2 and 3.2.3) the detailed description of each platform section is provided.

Car part, component, ... SEARCH

JOHN DOE
DISMANTLER

Combimeter

Disassembly route

From car to component

Component ID	Description of activity	Previous component to be disassembled	Disassembly time (min)
1	Removal of car dahsboard	-	2
2	Removal of top cover	1	3
3	Removal of bottom cover	2	3
4	Removal of combimeter	3	10

Total disassembly time **19 min**

Total disassembly cost 50.45 €

Estimated revenue

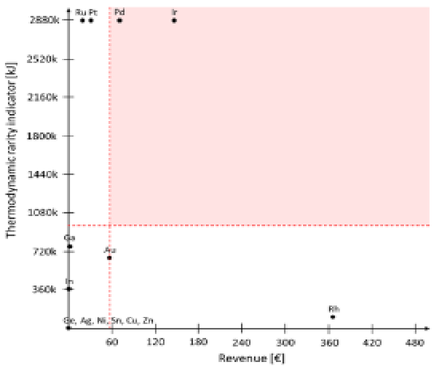
Material	Mass	Recovery rate	Thermodynamic rarity indicator	Revenue
Palladium (Pd)	1g	100%	2870.013 KJ	69.86 €
Iridium (Ir)	1g	100%	2870.013 KJ	145.04 €
Gold (Au)	1g	100%	654.683 KJ	57.41 €

Estimated disassembly cost 50 €

Desired profit margin 20 %

Thermodynamic rarity value limit 950 €

Desired profit margin 55 %



The ratio of revenue generatable from the sale of materials allocated in the red area of the chart is **25% greater** than the cost of disassembly

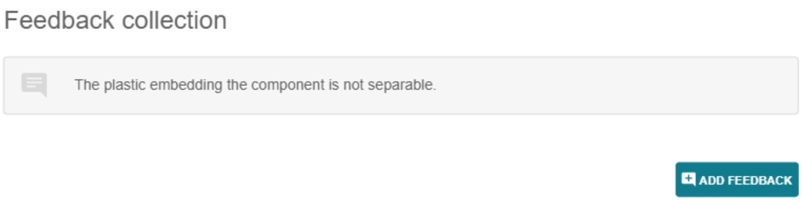
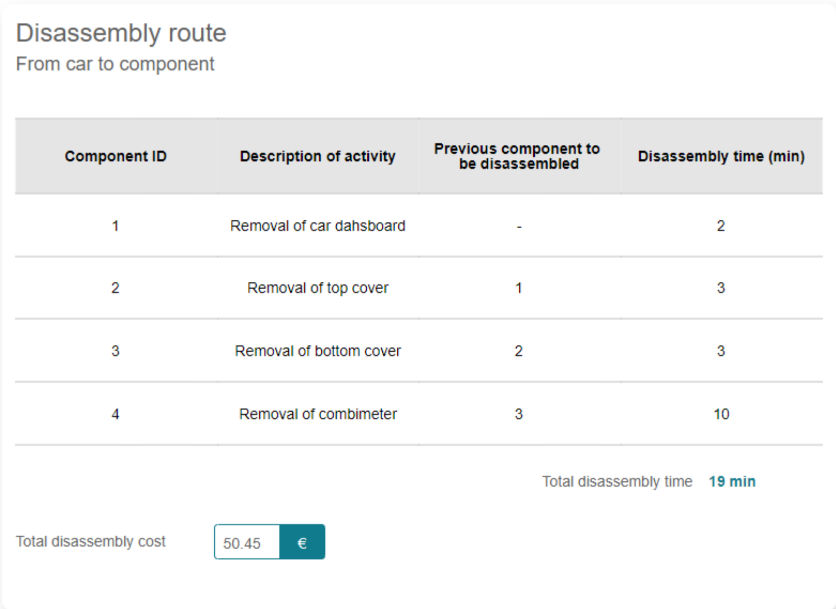


Figure 2 Disassemblability AI-based Advisory Tool: Homepage

After selecting the car part to examine, the platform displays the required data in two tables, followed by the feedback area assigned to collect comment the disassembly procedure suggested by the AI-based advisory tool. A detailed description of each platform section is provided in the following sub-chapters with a clearer figure.

3.1.1 Disassembly route section

The first chart describes step by step the necessary operations to perform to reach the final level of dismantling, starting from the whole car till the last indivisible part. For this reason, the third column reports the number of components that should previously undergo a disassembly procedure in a sequential order. For each operation, the average dismantling timing is shown with the total amount at the end of the table. According to this metric, the platform also presents the overall operation cost to provide a more complete analysis of the procedure to follow in order to facilitate the evaluation process.



Disassembly route
From car to component

Component ID	Description of activity	Previous component to be disassembled	Disassembly time (min)
1	Removal of car dahsboard	-	2
2	Removal of top cover	1	3
3	Removal of bottom cover	2	3
4	Removal of combimeter	3	10

Total disassembly time **19 min**

Total disassembly cost 50.45 €

Figure 3 Disassemblability AI-based Advisory Tool: Disassembly route section

3.1.2 Estimated revenue section

This section provides data with a more specific level of detail based on the chemical composition of the selected car part. The material list is displayed with indication of the key elements from an environmental and economic point of view. The metrics shown are:

- the mass,

- the recovery rate,
- the thermodynamic rarity indicator and
- the market value.

Moreover, the designer/decision maker can fill in some additional fields to perform a more detailed analysis of the disassembly route aligned with final user needs and specifications. These indicators, which can be identified by the green box, are:

- estimated disassembly cost
- desired profit margin
- thermodynamic rarity value limit
- limit value for revenue

The figures inserted in these indicators determine the chart below the table that represents in the red area those materials that are included in the range of the selected metrics as it's explained in the information box at the right of the cartesian plan. Similarly, the table shows in red the same components that comply with the edited parameters.

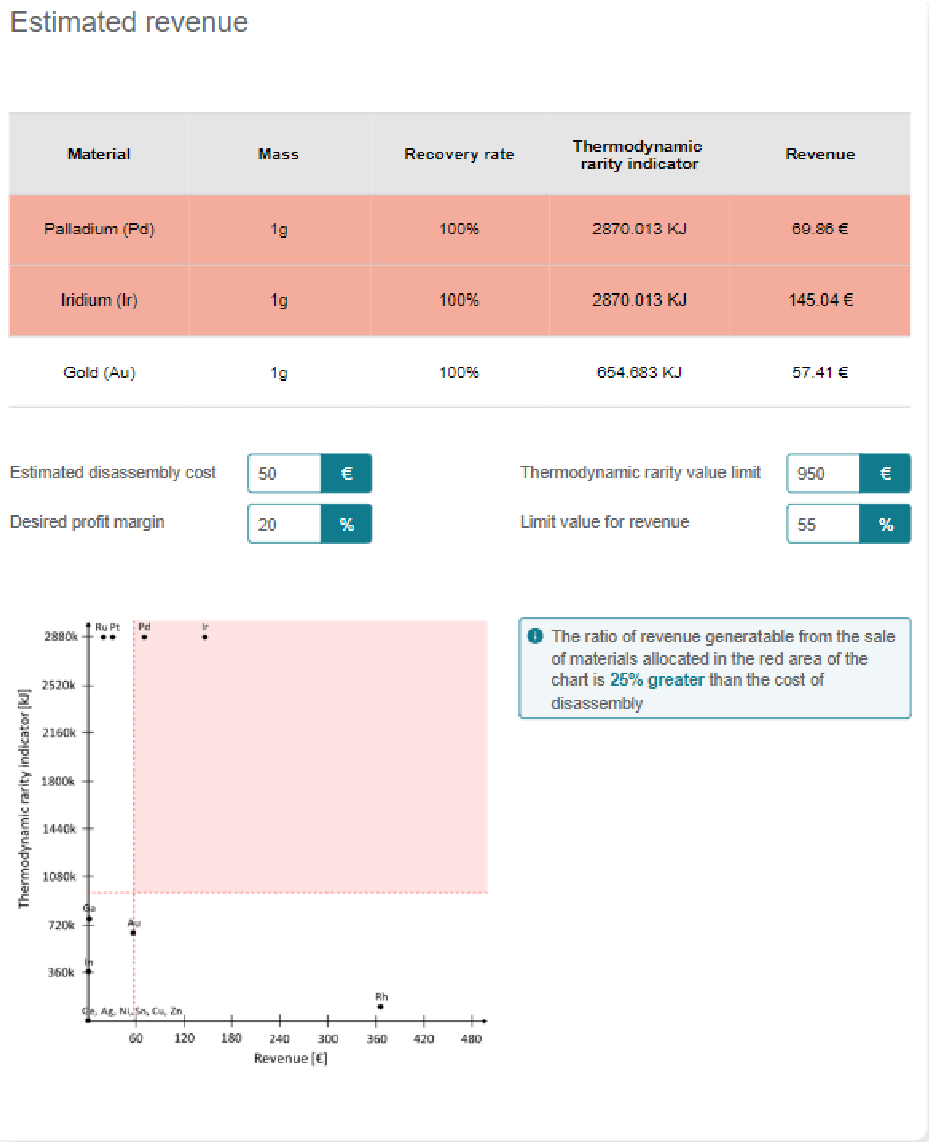


Figure 4 Disassemblability AI-based Advisory Tool: Estimated revenue section

3.1.3 Feedback section

Finally, the last section of this module is assigned to comments creation enabling the user to add personal feedbacks on the disassembly procedure or any other key information provided in the previous tables. All inputs created by the expert are here collected and displayed.

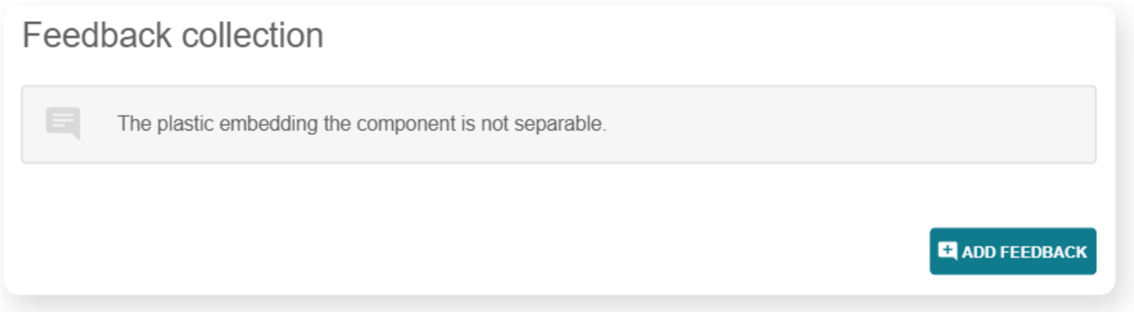


Figure 5 Disassemblability AI-based Advisory Tool: Feedback section

When the user clicks on the “Add feedback” button, the following pop us is displayed. The user can insert text with no character limitations, saving or discarding changes.

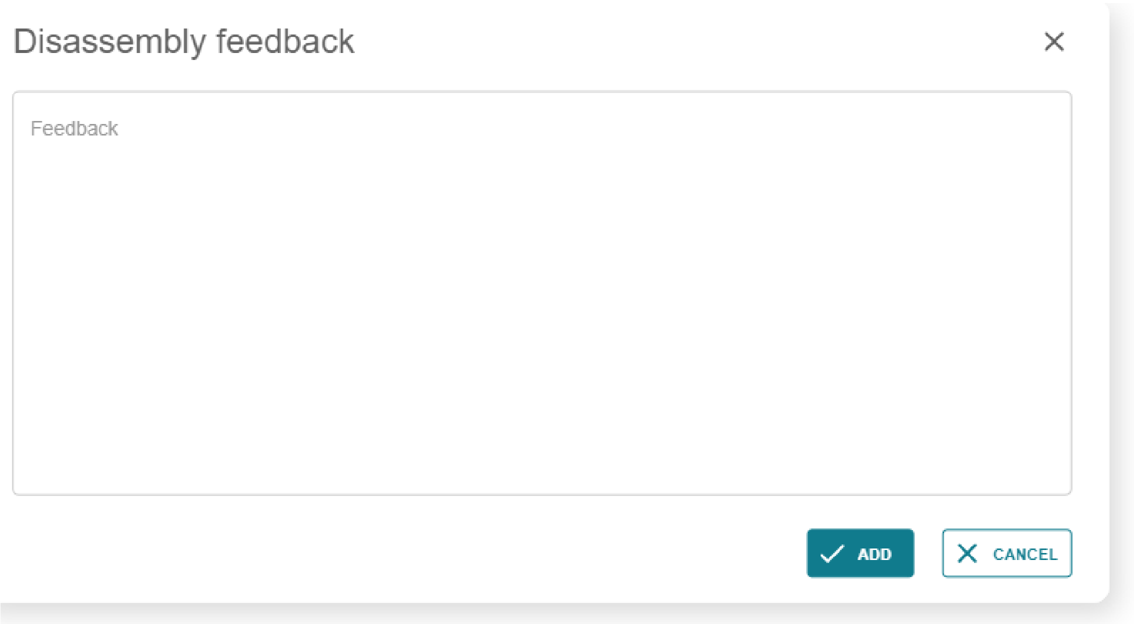


Figure 6 Disassemblability AI-based Advisory Tool: Feedback pop up

3.2 Recyclability AI-based Advisory Module

The Recyclability AI-based advisory module comprises a ranking of the suggested routes for the selected car component based on the Recycling Simulation tool analysis (used also in the Recyclability module of the Circularity Web Platform) integrated with the social and economic impact assessment.

After selecting the car part to examine, the platform displays the required data in a table, followed by an explanatory graphical representation and the feedback area assigned to collect comment the procedure suggested by the AI-based advisory tool. A detailed description of each platform section is provided in the following sub-chapters with a clearer figure.

TREASURE

Car part, component, ... SEARCH

JOHN DOE
RECYCLER

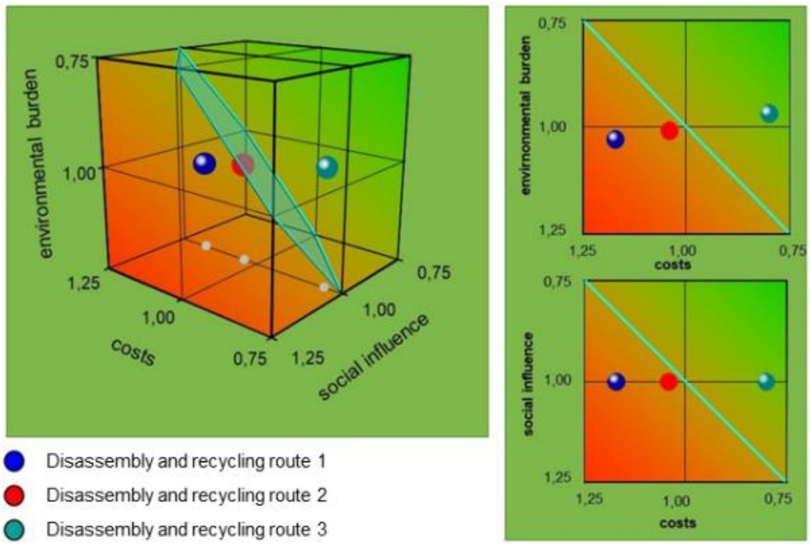
Combimeter

Disassembly & recycling routes advisor

From component to material

Route ID	Description of activity	Recycling Simulation Tool ranking	Social impact assessment	Social assessment ranking	Economic impact assessment	Economic assessment ranking	
1	-	3	-	2	-	1	
2	-	2	-	1	-	3	
3	-	4	-	4	-	4	
4	-	1	-	3	-	2	

Graphical integration approach



Feedback collection

Recycling route 1

The plastic embedding the component is not separable.

Recycling route 1

...

ADD FEEDBACK

Figure 7 Recyclability AI-based Advisory Tool: Homepage[2]

3.2.1 Disassembly and Recycling route advisor section

In this table, the key information is presented. The list of proposed recycling path provides an overview of the major impact analysis within the project scope. Firstly, the LCA results are displayed, based on the outcomes provided in T3.3, followed by the social and economic impact assessment. Regarding the latter, the social analysis measures the effect of the decision to avoid material extraction while the economic study refers to the possible revenues that this process can generate.

Disassembly & recycling routes advisor

From component to material

Route ID	Description of activity	Recycling Simulation Tool ranking	Social impact assessment	Social assessment ranking	Economic impact assessment	Economic assessment ranking	
1	-	3	-	2	-	1	
2	-	2	-	1	-	3	
3	-	4	-	4	-	4	
4	-	1	-	3	-	2	

Figure 8 Recyclability AI-based Advisory Tool: Disassembly and recycling routes section

At the end of each row, an information button is foreseen. Clicking on it, a pop-up is displayed with more detailed data on critical raw materials, including mass, recovery rate and the three type of impact assessment shown in the aggregated table. This high granularity description provides comprehensive knowledge of the car part recovery rate and process effect at environmental, social and economic level that the platform user can exploit to provide a tailored-made solution to car manufacturers/recyclers/dismantlers.

[2] Since this is the first release of the Sustainability and Circularity AI-based Advisory Tool, the chart section in the Graphical integration approach is still under development. For this reason, the image presented in this figure is taken from Kolsch, D., Saling, P., Kicherer, A., Sommer, A. G., & Schmidt, I. (2008). How to measure social impacts? A socio-eco-efficiency analysis by the SEEBALANCE® method. International Journal of Sustainable Development, 11(1), 1. https://doi.org/10.1504/IJSD.2008.020380

Disassembly & recycling route 1

Selected materials **CRM**

Material	Mass	Recovery rate	Social assessment	Economic impact assessment	Environmental impact assessment
Palladium (Pd)	1g	90%	High risk	40.57 €	-
Iridium (Ir)	1g	90%	Medium risk	110.04 €	-
Gold (Au)	1g	90%	High risk	34.71 €	-

Figure 9 Recyclability AI-based Advisory Tool: Disassembly and Recycling route detail table

3.2.2 Route integration chart section

In addition to the data reported in the previous table, a graphical representation has been added in the form of a 3D chart that enables the user to understand at a glance the impact of selected disassembly and recycling routes in the three domains (environmental, social and economic). Each procedure is identified with a different colored dot in order to improve user experience.

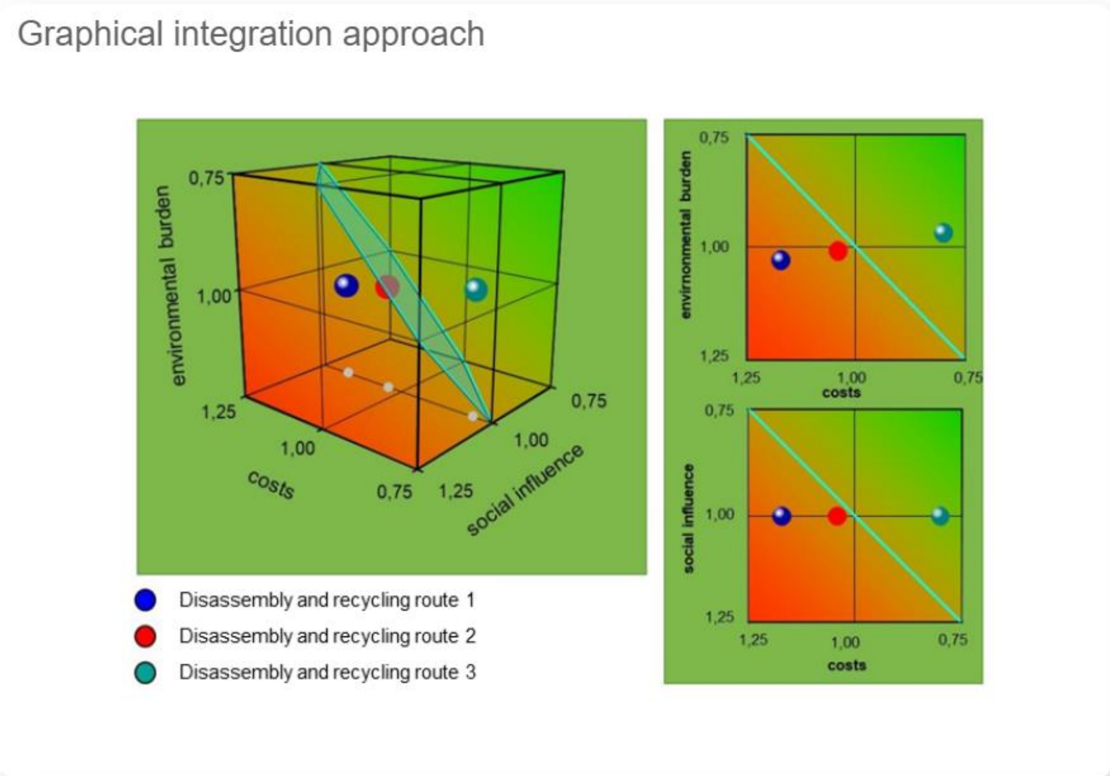


Figure 10 Recyclability AI-based Advisory Tool: Route integration chart section[3]

3.2.3 Feedback section

Finally, the last section of this module is assigned to comments creation enabling the user to add personal feedbacks on the disassembly and recycling procedure/s or any other key information provided in the first table. All inputs created by the expert are here collected and displayed by selecting on the drop-down menu the specific route to comment.

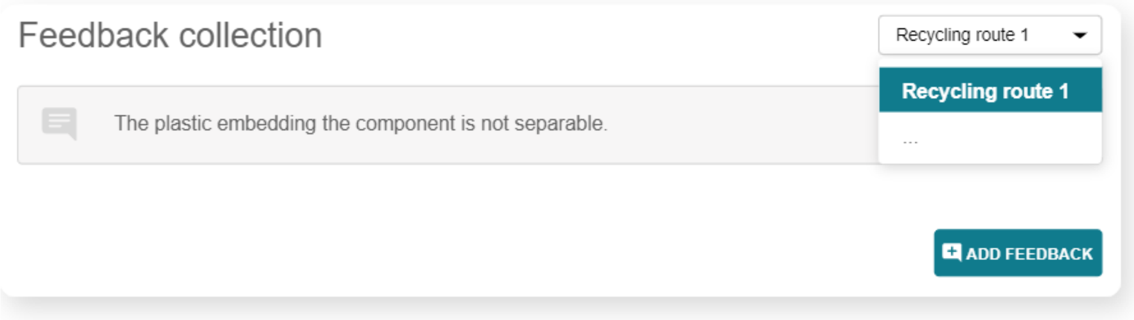


Figure 11 Recyclability AI-based Advisory Tool: Feedback section

When the user clicks on the "Add feedback" button, the following pop us is displayed. The user can insert text with no character limitations, saving or discarding changes.

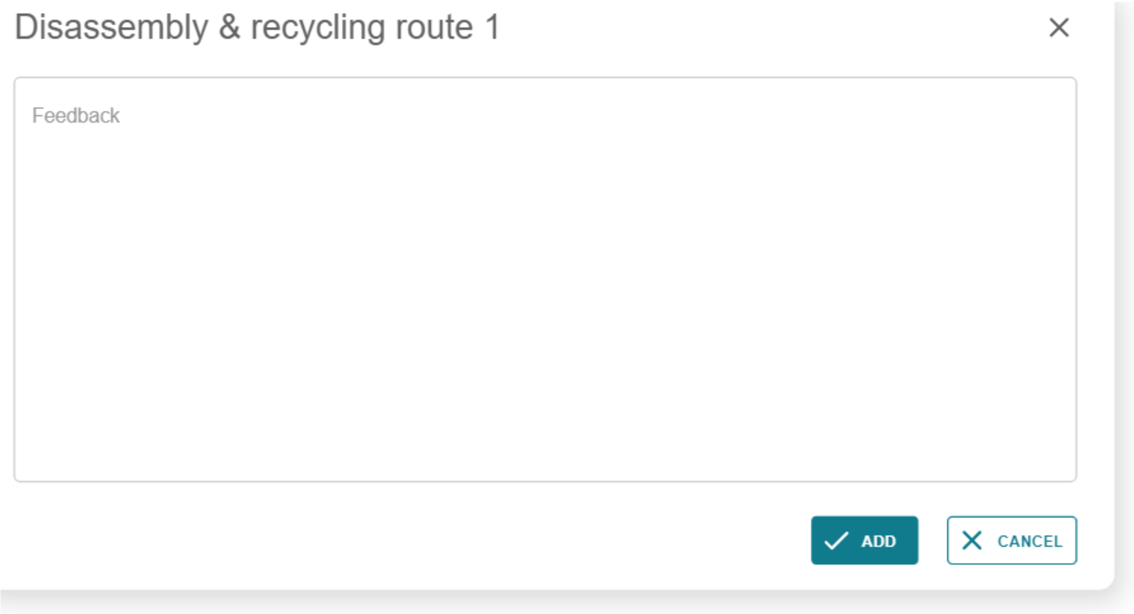


Figure 12 Recyclability AI-based Advisory Tool: Feedback pop up

3.3 Eco-Design AI-based Advisory Module

The Eco-design AI-based advisory module provides to vehicle and component manufacturers useful information to identify the most suitable car design according to specific KPIs. These

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3 Since this is the first release of the Sustainability and Circularity AI-based Advisory Tool, the chart section in the Graphical integration approach is still under development. For this reason, the image presented in this figure is taken from Kolsch, D., Saling, P., Kicherer, A., Sommer, A. G., & Schmidt, I. (2008). How to measure social impacts? A socio-eco-efficiency analysis by the SEEBALANCE® method. International Journal of Sustainable Development, 11(1), 1. https://doi.org/10.1504/IJSD.2008.020380

indicators have been previously defined based on both best practices and EU directives and dismantler and recycler feedbacks collected via survey. The data set concerns a wide range of suggestions to improve car part design, such as:

- the car components preferred position to facilitate access and disassembly;
- the key issues in which limit recycling rates which could be overcome by changing the design;
- recommendation on how to connect parts or components of interest to the rest of the car (e.g.: steelboard, plastic, etc.);
- elements that might affect the recovery process or might be lost due to the complex combination
- safety standards that could have an impact on car components connection and embedding

The homepage of the Eco-design advisory platform is split in 3 sections: the first is assigned to provide key information related to the existing design examining its compliance to specific guidelines in terms of disassembly and recyclability; the second is focused on performing the same analysis on the improved design created by the platform user; and in the third a comparison of the two designs is presented with respect to the guidelines selected in the upper part. Thus, the user must follow a specific step by step procedure to visualize data:

- step 1: the preliminary analysis of the existing designed is performed to define the critical issues related to disassembly and recycling procedures according to operator feedbacks and bibliographic knowledge
- step 2: assessment of old design compliance to eco-design guidelines: the eco-design process is based on meeting specific requirements in form of guidelines for both the disassembly and recycling level. According to which extend the old design compliances to these protocols, the platform provides a chart evaluating its conformity in different domains. The detailed description of this process is depicted in the following sub-chapter
- step 3: starting from the selected guidelines, the tool presents the related advisory message, stating the corrective action to implement in the improved design
- step 4: in this phase, the user performs step 2 analysis on the new design in order to evaluate the impact of the introduced improvements on the disassembly and recycling process
- step 5: a juxtaposition of the old and new design is presented for the guideline of interest with respect to the specific indicator with the aim at facilitating the comparison and evaluation of the 2 layouts

A detailed description of each platform section is provided in the following sub-chapters with a clearer figure.

3.3.1 Old design section

The upper section of the Eco-design advisory tool displays the 2D image of the selected car part with the key issues related to the disassembly and recycling process based on the feedbacks gathered from dismantlers and recyclers. A univocal and progressive number in red is assigned to each critical comment and it’s shown on the car component image to identify the position of the element to improve in the new design. To avoid numbers overlapping, the user can decide which messages should be displayed on the car part figure by clicking on the "eye" button at the feedback end.

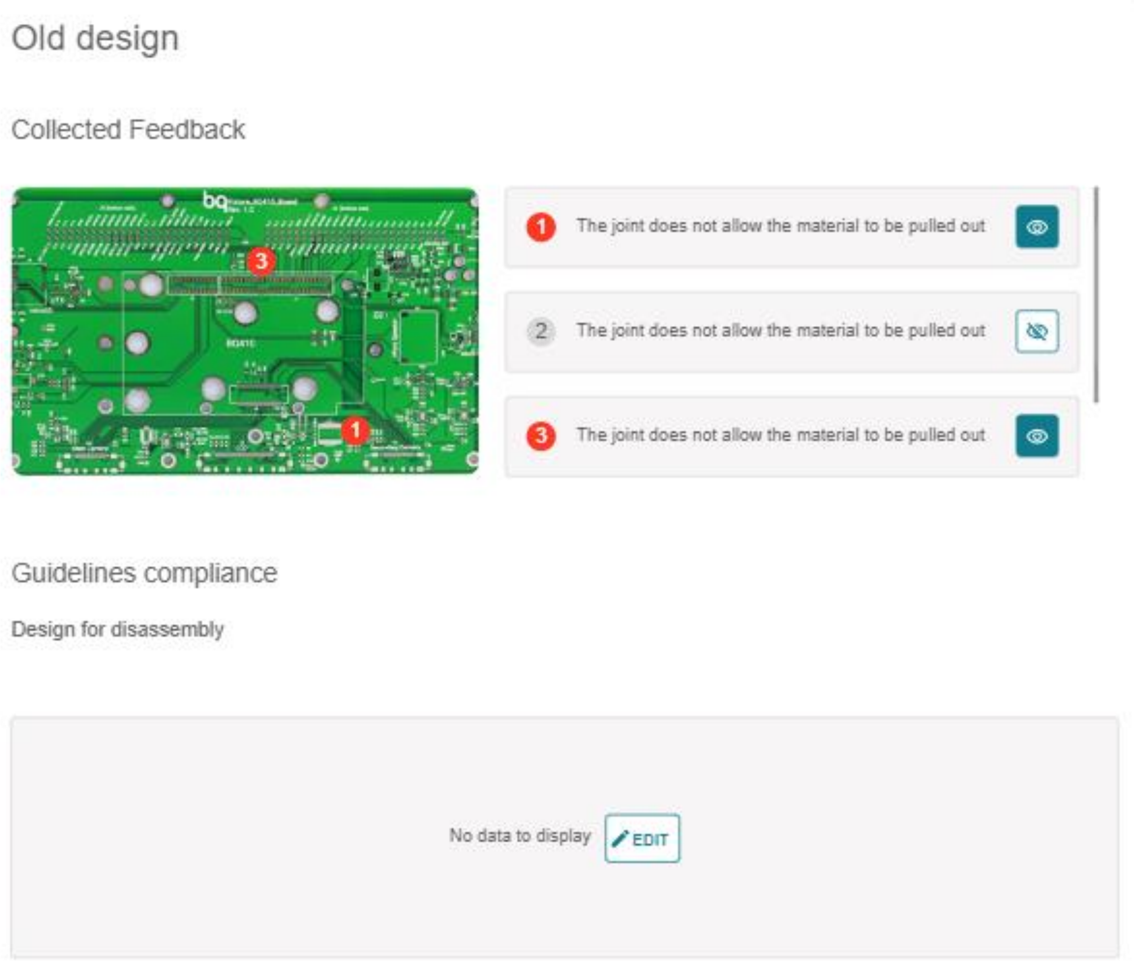

Figure 13 Eco-Design AI-based Advisory Tool: Old design section

The following part of this section, "Guidelines compliance" is dedicated to the analysis of design conformity to eco-design guidelines related to two parameters: Design for Disassembly (DfD) and Design for Recycling (DfR). The first defines the best practices to follow in creating the car component structure for an efficient dismantling procedure while the latter is focused on identifying the best design to improve the car part recovery rate. The single guidelines are bundled in major groups according to scope and goal they refer to. The "Guidelines compliance" section is blank until the user provides the required data related to the specific guidelines by clicking on the "Edit" button. After performing this action, the pop-up shown in the figures below is displayed: it consists in a table with the list of specific recommendations and related feedbacks that are part of the selected guideline group chosen through the drop-down menu on the upper left. To execute the analysis, the user must edit the "Margin of improvement" and "Relevance" columns enabling the automatic fill in of "Level of Circularity improvement" that multiplies the previous values. This table is shown both for the Design for Disassembly and Design for Recycling.

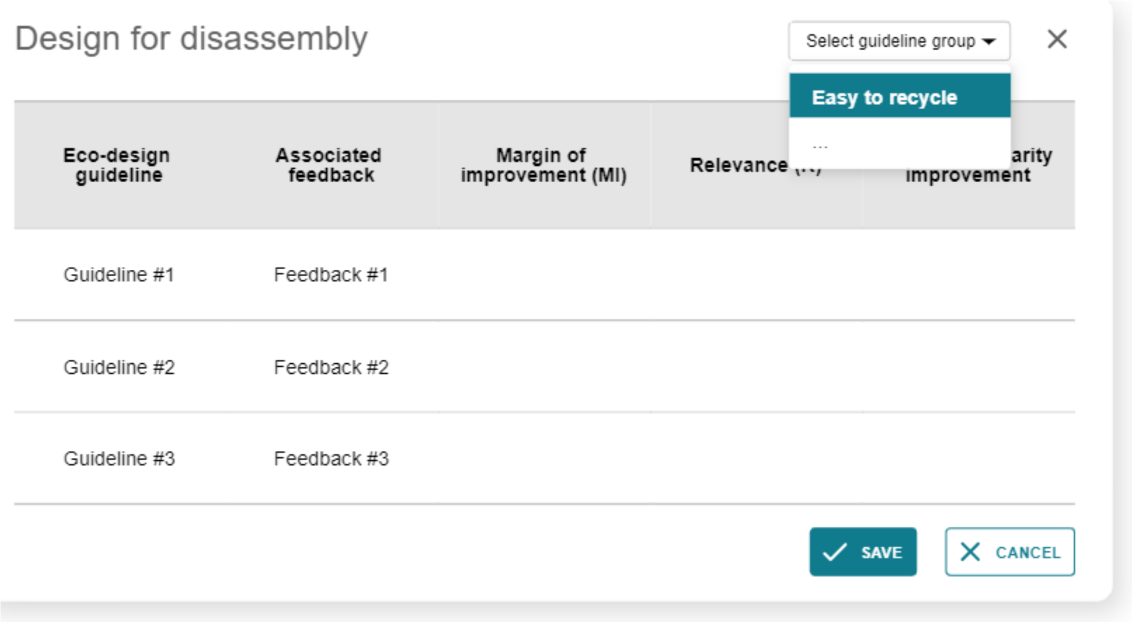

Figure 14 Eco-design AI-based advisory tool: table pop-up for DfD

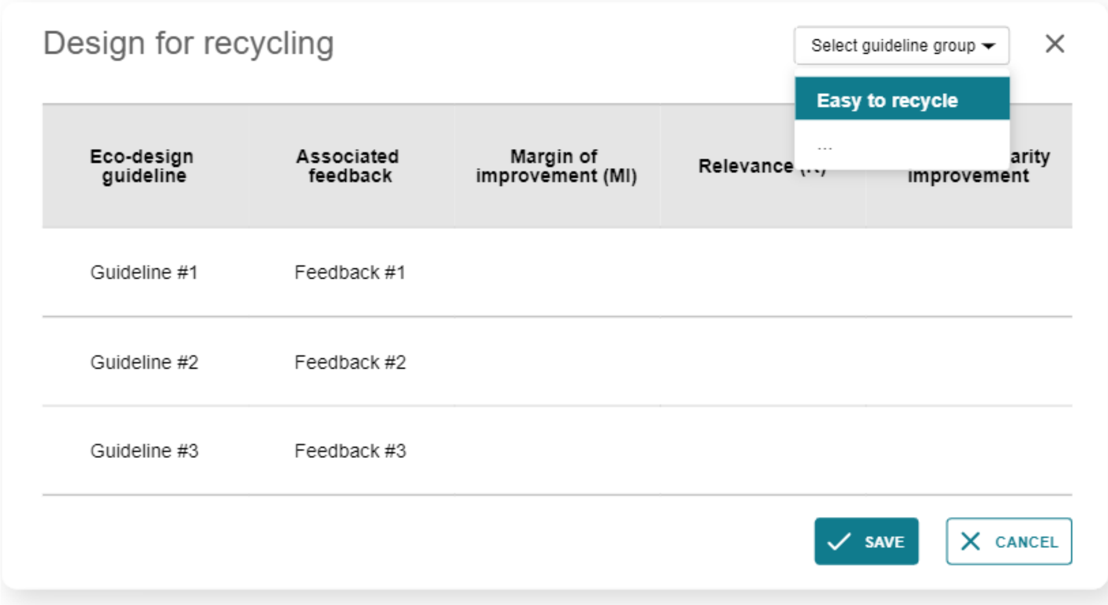

Figure 15 Eco-design AI-based advisory tool: table pop-up for DfR

Thanks to the information provided by the user in these two tables, the "Guidelines compliance" section of the homepage presents radar charts that comprise the data analysis for both the DfD and DfR. This type of graphic representation has been chosen due to its clearness, comprising key factors that affect car part design with respect to disassembly and recycling procedures. On the right, the radar chart presents an overall evaluation of the layout based on its conformity to all guideline groups. On the right, the user can check the design compliance to a specific set of recommendations by clicking on the guideline group of interest in the list. Thus, the chart changes according to user preferences and needs by displaying the single guideline values that are contained in the guideline group.

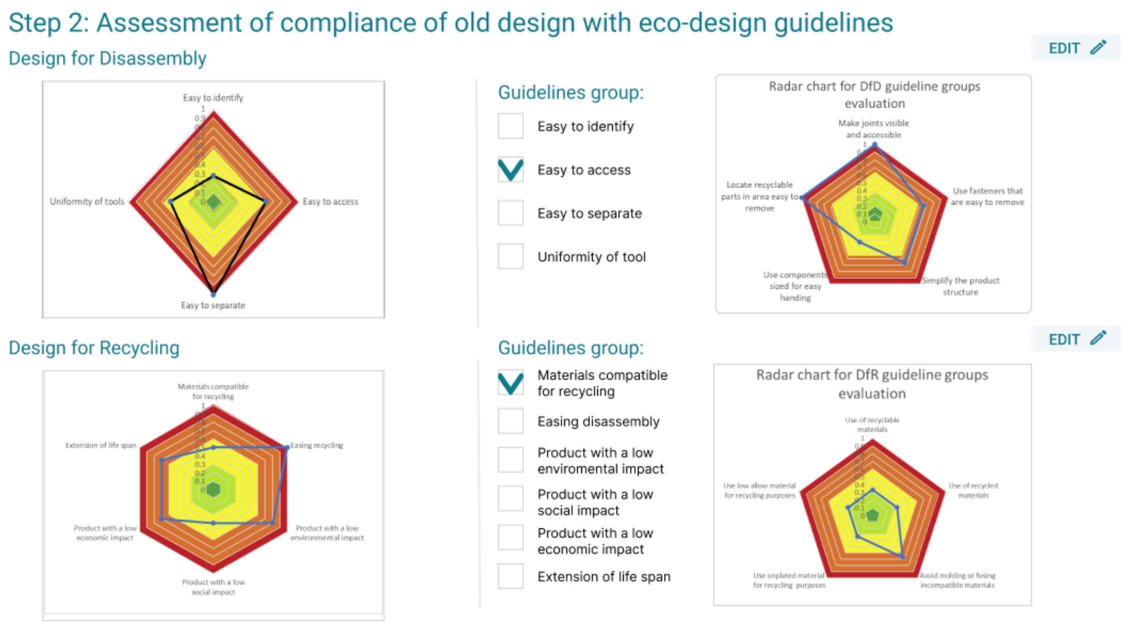

Figure 16 Eco-Design AI-based Advisory Tool: Old design section with radar charts

The following sub-section "Advisory" matches the information provided by the guideline group with the image displayed in the upper part of the dashboard. After choosing the recommendation group through the drop-down menu in the upper right, the table presents the guideline with its associated feedback that provides useful information for improvement of car design to facilitate the disassembly and recycling procedure. The last column shows the suggestion with a numbered red dot that refers to the same feedback provided in the first sub-section "Collected feedback". This enables the user to quickly localize the design area that should be improved. This procedure is performed for both the DfD and DfR based on the specific guideline groups.

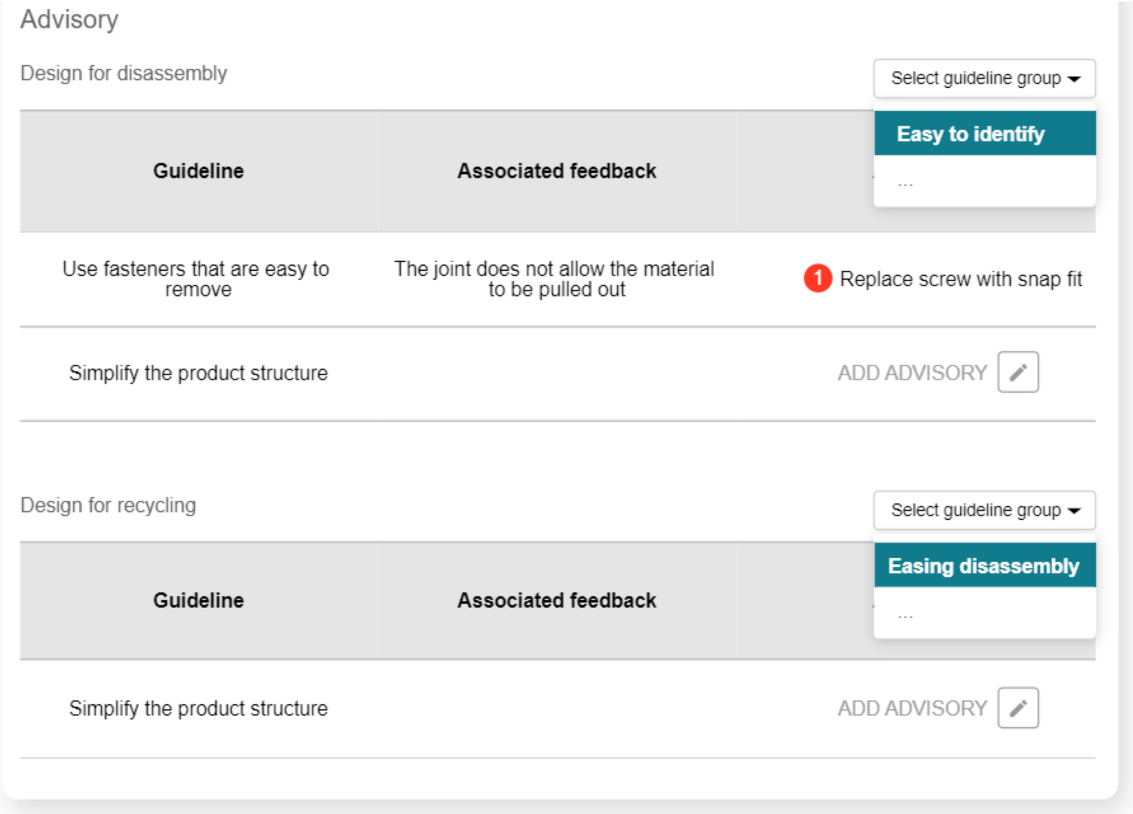

Figure 17 Eco-Design AI-based Advisory Tool: Old design section DfD and DfR

3.3.2 New design section

This part of the Eco-design AI-based Advisory Tool is focused on the evaluation of the improved design compliance to the same type of guideline groups with respect to DfD and DfR. Before presenting the analysis results, a key is displayed to facilitate outcomes interpretation. In this section the user can assess the new design conformity for each guideline group by choosing from the drop-down menu the level of compliance. Moreover, in the last column it's also possible to write a comment explaining the key factors that had an impact on the decision. Finally, the user can export the information provided in this table for future reference and use.

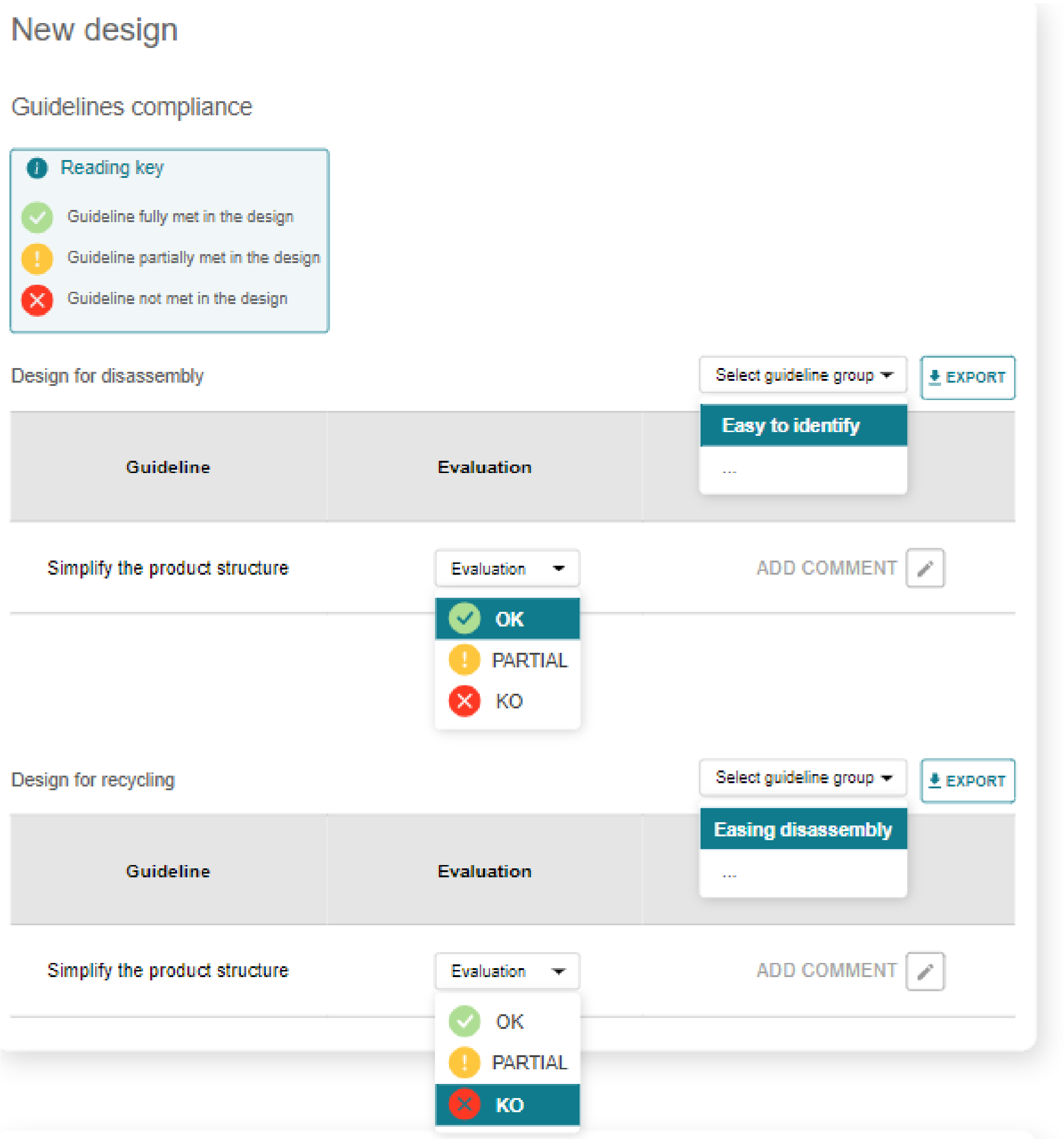

Figure 18 Eco-Design AI-based Advisory Tool: New design section

3.3.3 Old vs New design comparison section

This last section is assigned to compare the existing and improved design based on the thermodynamic rarity indicator in connection with a specific guideline group the user can choose using the drop-down menu. The bar chart graphically represents the preferred layout using a major metric also applied in the Disassemblability analysis and shown in its related module of the Circularity Web Platform.

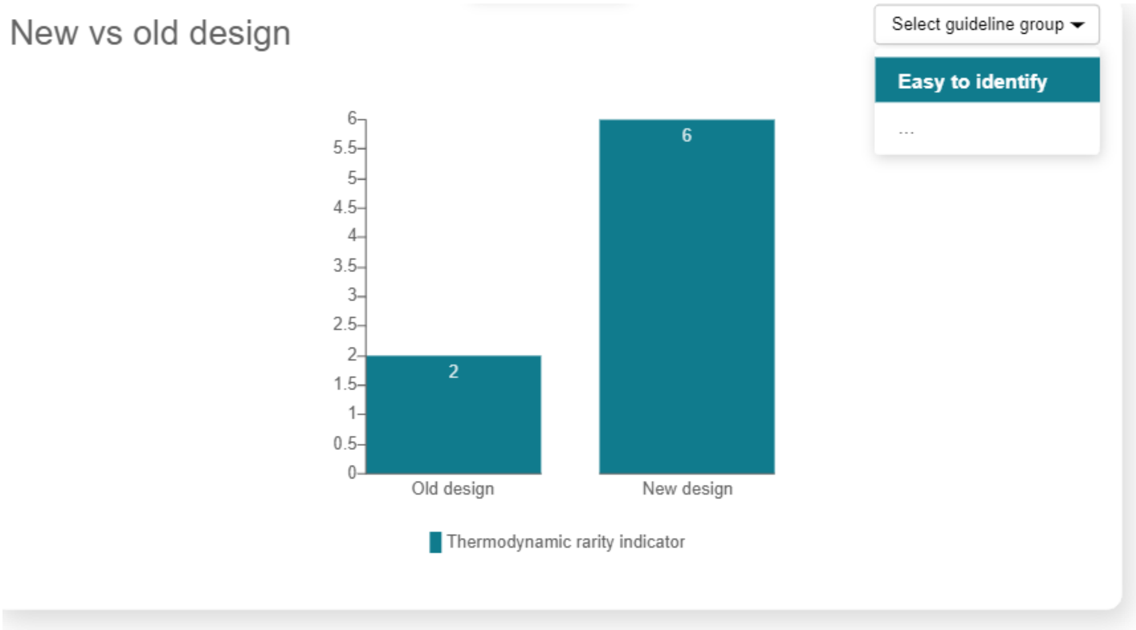

Figure 19 Eco-design AI-based Advisory Tool: Old vs new design comparison section

4 Conclusions and Next Steps

The present deliverable documents TREASURE Circularity AI-based Advisory Tool as a result of the outputs regarding technical requirements and applied methodology as pinpointed in D2.2, deriving not only from the preliminary system analysis but also from the discussion with the industrial use cases. A complete description of platform use in the three modules is presented, followed by a comprehensive depiction of each dashboard section with additional details related to tool features and user functionalities.

The next steps will be mainly focused on the execution of the other tasks foreseen in T4.5, assigned to technical design, implementation, and integration of the AI-Based Advisory modules. Since this preliminary version of the AI-based Advisory Tool has been implemented taking into consideration one car part only as a pilot case, a key activity to put in action in the next months will concern the replicability of the process described for all other car components selected with the project scope. Moreover, additional interactions with the pilots are needed to better select the sustainability and circularity indicators to be exploited in the decision-making support and to further investigate the needs of data for the Life Cycle Sustainability & Circularity Assessment that is the base for the KPIs calculation that are in turn supporting the sustainability & circularity advisory.

The activities will be carried out collaborating with the other Work Packages, mainly WP4 since the advisory development is strongly correlated to the Circularity Web Platform and the outcomes emerging from its modules. Moreover, the other affected WPs include: WP3, aimed at providing the main contents of the modules; WP5, aimed at providing a testing simulation, and WP6, aimed at providing a final validation of the TREASURE platform and its technical implementation. The final version of the Circularity AI-based Advisory Tool will be provided in D4.10 due on M33 as a result of the refinement of technical developments concerning all platform components, in addition to emerging end user needs and requirements.

Abbreviations

MISS	Material Information Sheet System
CE	Circular Economy
WEEE	Waste Electrical Electronic Equipment
EEE	Electrical and Electronic Equipment
GUI	Graphic user interface
DfD	Design for Disassembly
DfR	Design for Recycling