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Zero Emission electric Vehicles enabled by haRmonised circulArity

Deliverable 1.3

Harmonized design: Repository of DfC Strategies

30th September 2024

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16 September 2024	V1	Results compilation, structure and writing of the report
20 September 2024	V2	Polished after review
30 September 2024	V3; Final version	Formatting and polishing
07 January 2025	V4	Revised version 1
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ZEvRA project abstract

ZEvRA's main objective is to improve the circularity of light-duty EVs throughout their entire value chain, from materials supply and manufacturing to end-of-life (EoL) processes, which aligns with the European Union's goal of achieving zero CO2e emissions by 2035, particularly in the EV value chain. To do so, ZEvRA will develop a Design for Circularity (DfC) methodology and a holistic circularity assessment aimed at improving the production of electric vehicles (EVs) based on the 9Rs. This methodology will be validated by developing zero emission solutions for the most important automotive materials, covering > 84% material mix: steel, three versions of aluminium (wrought, casting, and foam), thermoplastics composites (long and continuous fibre-reinforced), unfiled/short fibre plastics, glass, tyres and Rare Earth Elements (REE). These solutions will be supported by a set of digital tools to support the manufacturing of the use cases, the assessment of circularity, traceability, and the virtual integration of components into a full replicable vehicle.

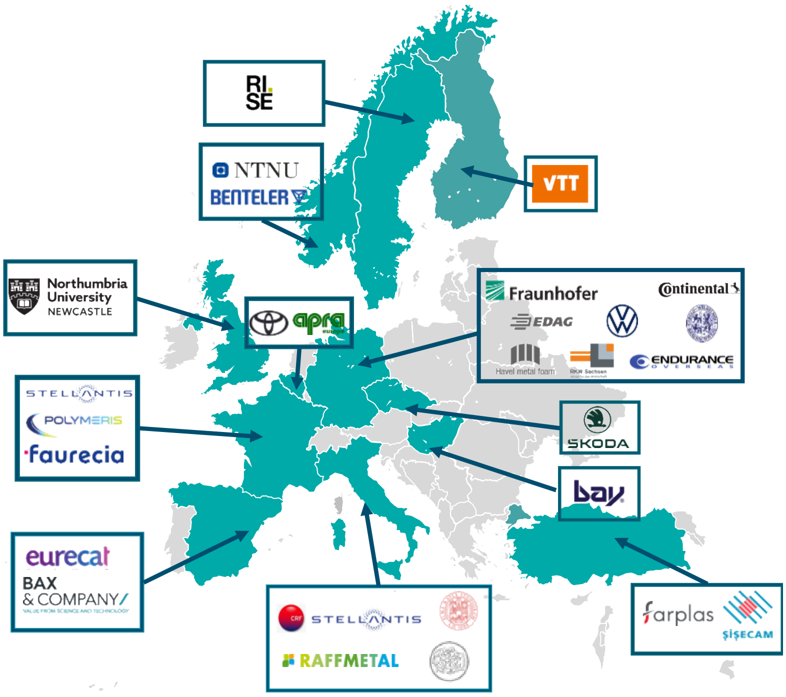

Figure 1: *ZEvRA consortium*

To maximise the outreach of our methodology and zero emission solutions, ZEvRA will develop a dedicated training & upskilling programme for the automotive workforce and academia, together with activities aimed at increasing awareness & acceptability of the proposed zero emission solutions. Lastly, circular business models targeting EoL and logistics aimed at improving the economic feasibility of circularity in EVs are advanced. ZEvRA's innovations aim to improve zero emission approaches in the life cycle and value chain of at least 59% of European EVs by 2035 through the 5 OEMs and Tier 1's that are part of the consortium (Figure 1), which includes industry and academia covering the entire automotive value chain.

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Abbrevations and Acronyms

Abbr.	Full name
DfC	Design for Circularity
EV	Electric Vehicle
CEAP	Circular Economy Action Plan
PDSA	Plan-Do-Study-Act
LCT	Life Cycle Thinking
REE	Rare Earth Elements
MMP	Methodological Management Plan
OEM	Original Equipment Manufacturer
RI	Research Institutions
AS	Automotive Suppliers
CY	Consultancy
CA	Cluster Associations
CO	Use case owner

Executive summary

As the automotive industry faces pressing environmental challenges, the need to transition towards a more sustainable and circular economy, becomes more critical. This report underscores the practical application of the ZEvRA Design for Circularity (DfC) Methodology established in D1.1, to identify viable circular approaches for ZEvRA use cases and define concrete actions that enhance the circularity and sustainability throughout the use cases lifecycle.

D1.1 provided a methodological framework that in addition with the 9R strategies aims to foster more sustainable and circular performance throughout the EV lifecycle. As part of the DfC process, a series of workshops has been conducted to facilitate the collaboration between project partners and apply Step 3: Re-adaption of Technological Procedures to Selected Strategies and Step 4: Selection of Concrete DfC Actions and Conceptualized Design of the methodology.

Building on the foundational work established in D1.1, through the application of the ZEvRA Design for Circularity Methodology, this report presents the insights collected from the two workshops corresponding to steps 3 and 4 of the methodology. The first workshop assessed the feasibility of the application of the different 9Rs to ZEvRA use cases, while the second workshop provided a platform for collaboration, enabling a brainstorming on the specific DfC actions for each use case.

From the first workshop it can be concluded that the most feasible strategy in most use cases is R8 Recycling, though R2 Reduce is also considered somewhat feasible as well. The second workshop included the use of AI to optimize resource use, the standardization of design and material classes as well as an increased use of secondary materials to reduce dependency on primary resources.

This report concludes the first iteration of ZEvRA's DfC Methodology, establishing a foundation for the continued refinement, in collaboration with all ZEvRA's consortium, in pursuit for a more sustainable and circular EV.

1 Introduction

Building on the foundational framework established in D1.1, present report aims to apply the comprehensive ZEvRA's Methodology on Harmonized Design for Circularity to the already defined relevant aspects of an electric vehicle, as described in ZEvRA's proposal. As pressing environmental challenges related to the automotive industry underscore the necessity of implementing a robust DfC methodology to transition towards more sustainable practices and minimize end-of-life wastage in the automotive sector.

D1.1 outlined the methodological framework and the management plan for ZEvRA's Harmonized Design for Circularity, emphasizing the importance of efficient material and energy use, as well as enhanced circularity strategies. By integrating the 9R's into the methodology, the aim is to establish circularity requirements that promote resource efficiency and improved environmental performance throughout the vehicle lifecycle. The alignment with the EU Green Deal[1] goals and the requirements of the digital product passport as part of the Ecodesign for Sustainable Products Regulation[2] and one of the key actions under the Circular Economy Action Plan (CEAP)[3] remain central to the efforts.

To ensure the practical implementation of ZEvRA's Methodology, a series of collaborative efforts, including training and interactive workshops, were initiated. These activities have set the stage for stakeholder engagement, facilitating the exchange of ideas, feedback, and the definition of DfC strategies and specific actions. The workshops have been pivotal in fostering a collaborative environment, where stakeholders from various sectors contribute to refining and aligning the DfC strategies with industrial and European sustainability goals.

In this report, the application of ZEvRA's Methodology is detailed through the insights and outcomes derived from two key workshops. These workshops served as platforms for discussing, evaluating, and defining specific DfC strategies that address the environmental challenges faced by the automotive industry.

The first workshop focused on the Re-adaption of Technological Procedures to the 9R Strategies identifying the critical areas for circularity improvements across the different use cases of ZEvRA project. The second workshop concentrated on developing actionable strategies and aligning them with the overarching goals of the project. Insights from these sessions are instrumental in formulating specific DfC strategies tailored to each use case, (steel, wrought aluminium, casting aluminium, foam aluminium, plastics, composites, glass, tyres, and rare earth elements).

The strategies are categorized as the 9R categories as well: smarter use and manufacture, lifespan extension, and useful application of materials, where each category encompasses a range of specific actions and interventions that collectively aim to enhance the sustainability of the automotive sector.

As we proceed with the detailed application of ZEvRA's Methodology in the subsequent sections of this report, the insights gained from the workshops will be instrumental in guiding the DfC approach. Through stakeholder collaboration and the established comprehensive framework, significant advancements in sustainable automotive design and practices are anticipated.

2 Methodological framework and Management Plan

The methodological framework for this report continues to evolve from the principles and processes established in D1.1, emphasizing on embedding circular economy principles into the product design process. This approach aims to challenge and transition from a linear economic model -characterized by a sequence of producing, consuming, and disposing- to a circular one, where resource loops are closed, and environmental impacts are minimized through ecodesign strategies. These strategies are grounded in the life cycle perspective, ensuring that environmental, economic and social considerations are integrated throughout the product's development, along with circularity. The ultimate objective is to foster the creation and closure of resource loops, thereby reducing environmental impact and decoupling economic growth from resource depletion.

The DfC framework, as introduced in D1.1, is structured around the Plan-Do-Study-Act (PDSA) cycle which facilitates a systematic and iterative approach to circular design and involves four key steps (Figure 2). This methodology is designed to be flexible and adaptive, allowing for continuous improvement and alignment with the evolving goals of the project. However, it is important to note that while the framework consists of four key steps, the iterative nature will allow for more detailed information in future iterations.

Figure 2: *DfC key steps (as presented in D1.1)*

Step 1: Identification of Hotspots and Life Cycle Stages

This initial step involves a thorough assessment of the case studies' life cycle to identify key aspects and stages, known as "hotspots" where impacts (on environment, economy and society) are identified as most significant. This step establishes the baseline from which all subsequent design strategies are developed. The methods used, such as Circularity Assessment and Life Cycle Thinking (LCT), have been instrumental in pinpointing these hotspots, providing a critical foundation for subsequent design strategies. During the workshops, relevant hotspots were identified and evaluated. The iterative revisiting of the hotspots is essential for maintaining an accurate and current understanding of the product's impact profile, which in turn informs the direction of the circular design efforts. Hotspots or critical areas are considered as the use cases defined for ZevRA's project, as these are considered the most important materials in a car, and altogether, cover most of the vehicle weight: Steel, Aluminium (wrought, casting and foam), Plastics and Fibre-reinforced Composites (Thermoplastic Composites and Mineral filled/Short fibre-reinforced plastic) and Glass, Tyres and REE.

Step 2: DfC Strategies Definition and Setup

Building upon the insights gathered in Step 1, the second step involves defining and setting up DfC strategies that align with the 9R Circularity objectives (Table 1). The second workshop, was pivotal in brainstorming strategies that are aligned with the overarching sustainability goals of ZevRA's project. This workshop provided an opportunity for the consortium to collaborate, evaluate the 9R strategies, and infer more specific strategies applied to the different case studies.

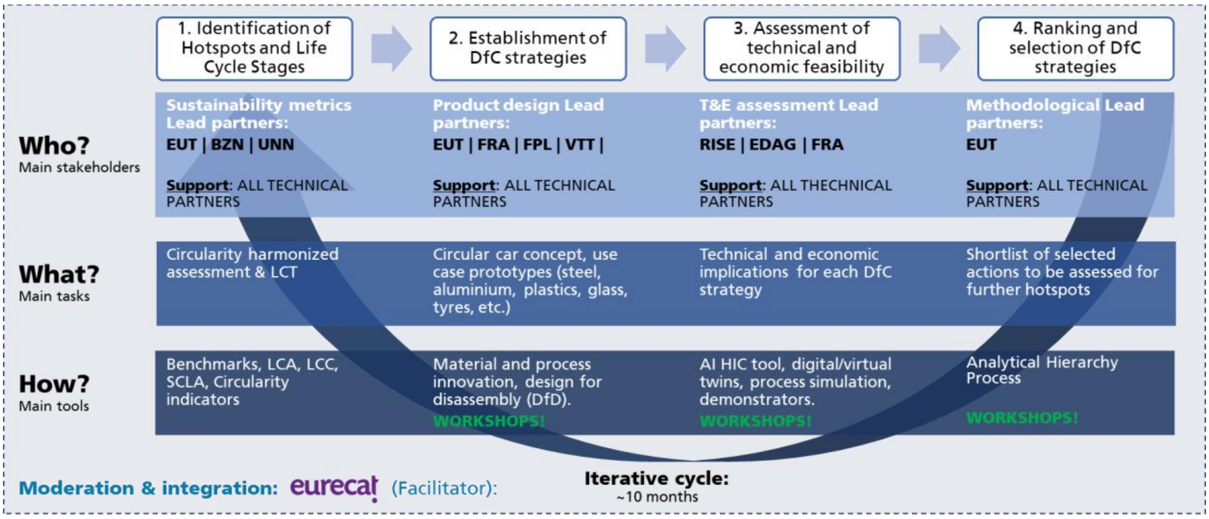

Figure 3: *Graphical summary of the Methodology Management Plan*

Table 1: *9R strategies* [4]

Smarter product use and manufacture	R0	Refuse	Make product redundant by abandoning its function or by offering the same function by a radically different (e.g. digital) product or service
	R1	Rethink	Make product use more intensive (e.g. through product-as-a-service, reuse and sharing models or by putting multi-functional products on the market)
	R2	Reduce	Increase efficiency in product manufacture or use by consuming fewer natural resources and materials
Extend lifespan	R3	Reuse	Re-use of a product which is still in good condition and fulfils its original function (and is not waste) for the same purpose for which it was conceived
	R4	Repair	Repair and maintenance of defective product so it can be used with its original function
	R5	Refurbish	Restore an old product and bring it up to date (to specified quality level)
	R6	Remanufacture	Use parts of a discarded product in a new product with the same function (and as-new-condition)
	R7	Repurpose	Use a redundant product or its parts in a new product with different function
Useful application of materials	R8	Recycle	Recover materials from waste to be reprocessed into new products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations
	R9	Recover	Recovery of (embodied) energy from wastes and residue

As it was described in D1.1, a Methodological Management Plan (MMP) has been developed to ensure a cohesive and structured implementation of ZEvRA's Harmonized DfC Methodology throughout the project's lifespan. Figure 3 offers a visual overview of the MMP. The MMP leverages a Who/What/How framework to clarify the roles of Main partners, Support partners, and Facilitators, ensuring the project remains aligned with the planned objectives while promoting the flow of information among all stakeholders. The MMP structure, which emphasizes equal importance among the roles, has been critical in organizing the collaborative efforts of the recent workshops.

During the recent workshops, the MMP was put into action to engage key stakeholders, including Main and Support partners, as well as the Facilitator, who ensured that the methodology was applied effectively.

Step 3: Re-adaption of Technological Procedures to Selected Strategies

Having the DfC strategies identified, the following step comprises adapting technological processes to align with the chosen approach. This requires a comprehensive assessment of feasibility and viability in terms of technical, economic, and social factors to ensure the effective implementation of adjustments across manufacturing, material selection, and product design. Feasibility assessments play a key role in determining the practicality of possible strategy application, ensuring they can be successfully integrated into existing systems and workflows. The main goal is to reduce resource consumption while enhancing circularity throughout the product lifecycle.

While evaluating the application of the 9Rs strategies, four critical areas were considered: feasibility, compatibility, performance, and regulatory compliance. At the same time, in economic terms, cost and market demand are key factors, ensuring that the strategies are financially viable and align with consumer preferences reality. Similarly, socially, ensuring that employee well-being, community relations, and inclusivity are supported throughout the entire supply chain is key.

Step 4: Selection of Concrete DfC Actions and Conceptualized Design

This final step targets the definition and selection of specific DfC actions integrating the vision of viability and feasibility from the previous step.

In the next iterations of the application of the methodology, it is expected to include Life Cycle Thinking (LCT) assessments results as well as the Circularity Index to guide the selection of key circular actions. At this stage of the project, there are no results available to do so.

3 Implementation

Two different workshops were successfully held. The first workshop focused on the Re-adaption of Technological Procedures to Selected Strategies across the different use cases of ZEvRA project. The second workshop concentrated on developing actionable strategies and aligning them with the overarching goals of the project.

3.1 First Workshop: Re-adaption of Technological Procedures to Selected Strategies

Date: June 18th, 2024

Total of 53 participants (see Table *2*)

Table 2: *List of participants of the first workshop*

Number of Participants	Institution
2	Fraunhofer IWU
1	Northumbria UK
5	Eurecat
4	Bayzoltan
1	UNIBO IT
5	Skoda
3	Polymeris
2	RKW
1	RISE SE
1	Faurecia
2	EDAG DE
1	Raffmetal IT
2	TU Braunschweig DE
2	Farplas
2	Benteler
1	NTNU NO
1	APRA DE/BE
1	Endurance DE/IT
2	Volkswagen
1	Politecnico Milano IT
1	Continental
1	Sisecam
4	VTT
2	BaxCo
1	Toyota
3	Stellantis
1	CRF IT

This workshop began with a theoretical session aimed at refreshing participants' knowledge of the 9R framework: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle, Recover. This foundational part of the workshop ensured that all attendees were aligned in their understanding of each strategy's purpose and potential application within the context of EVs. The content for the theoretical session was prepared and presented in practical leaflets for each of the 9R DfC strategies as it follows on Figure 4 to Figure 13.

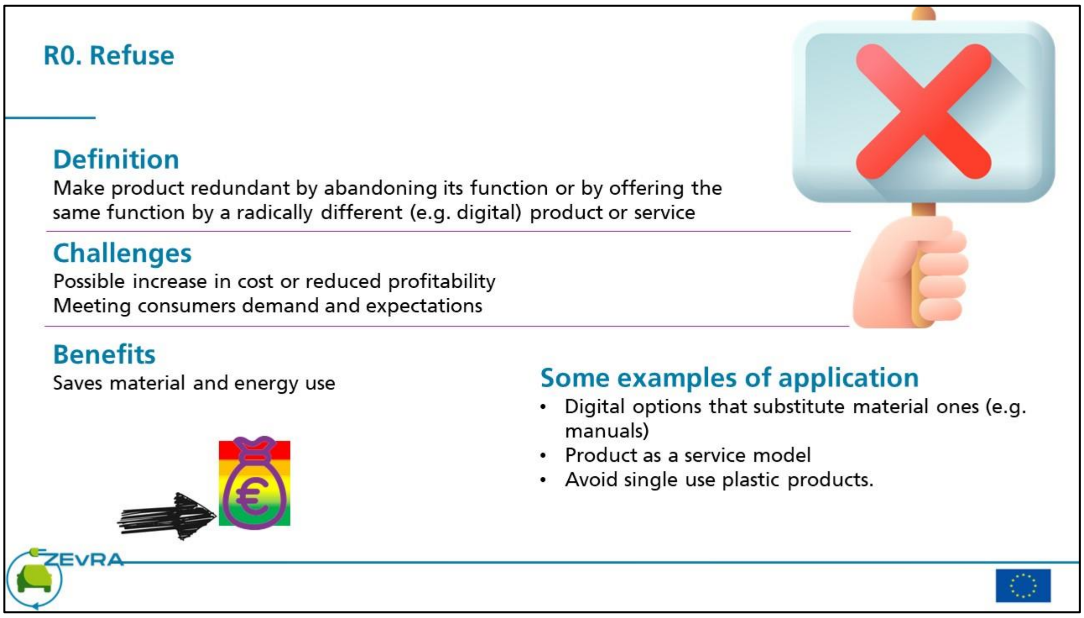

Figure 4: *R0 Refuse leaflet*

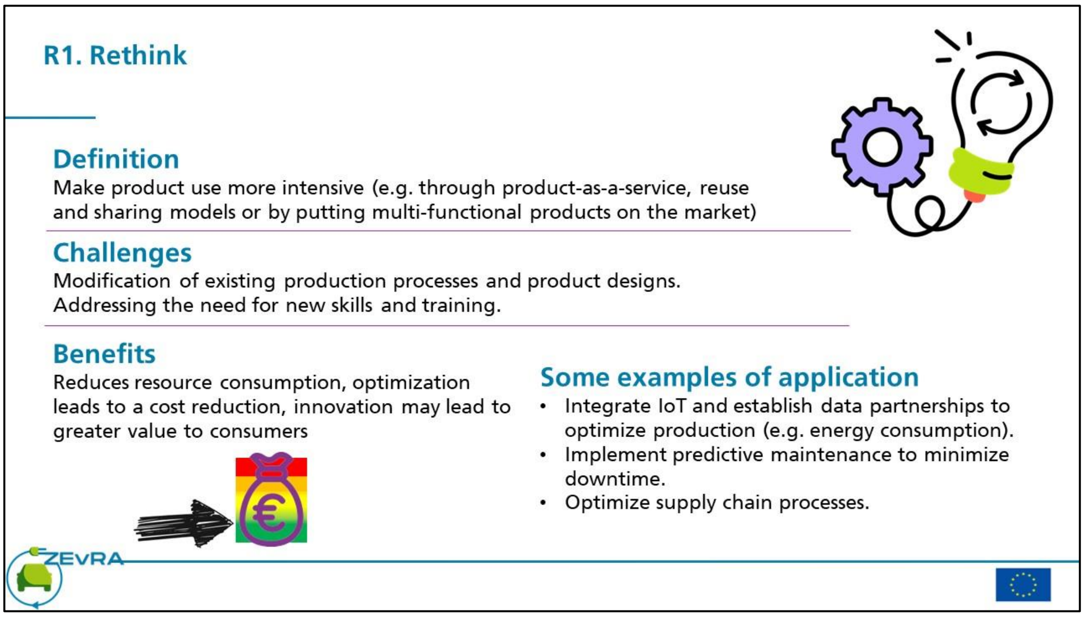

Figure 5: *R1 Rethink leaflet*

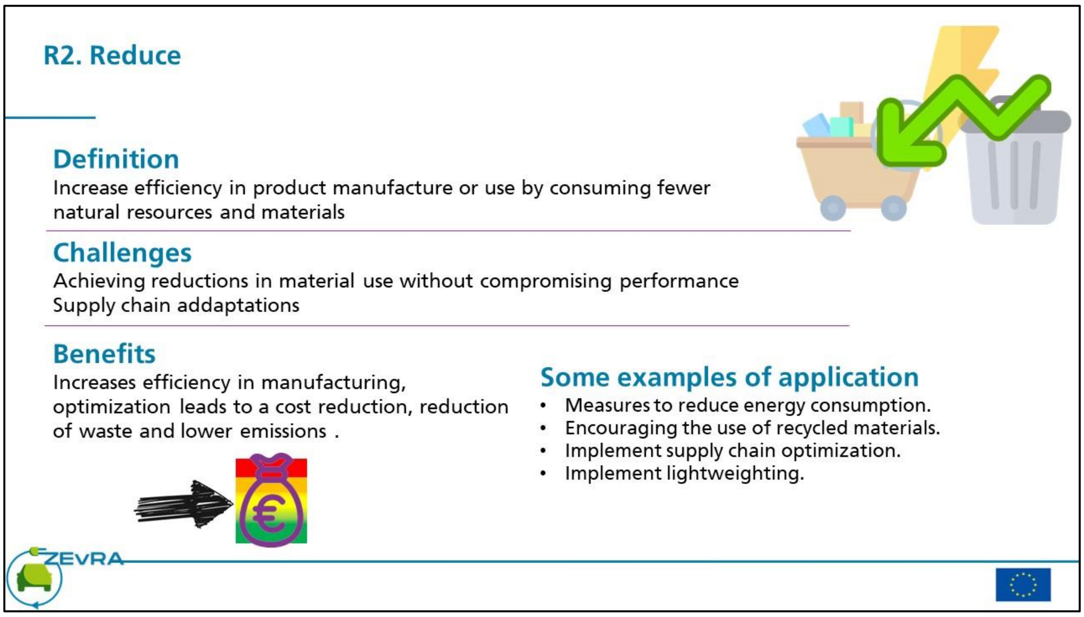

Figure 6: *R2 Reduce leaflet*

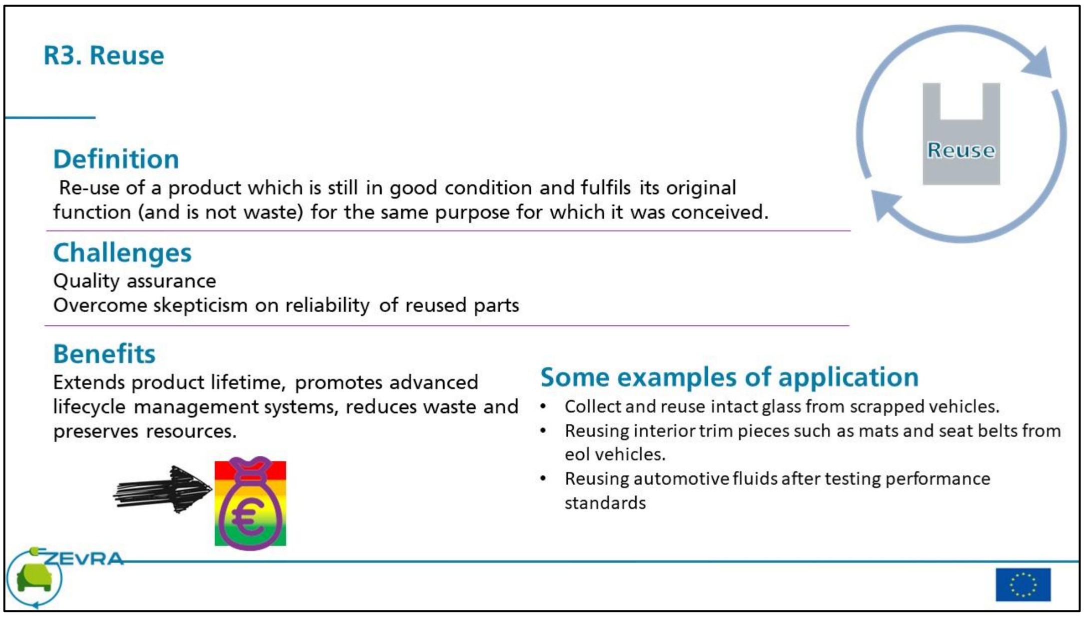

Figure 7: *R3 Reuse leaflet*

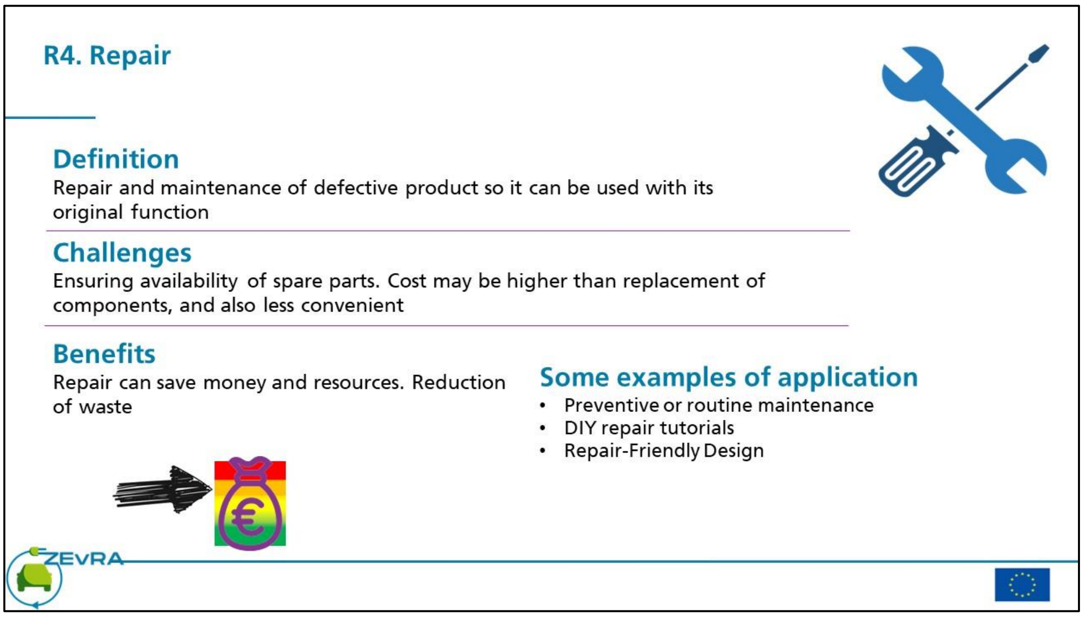

Figure 8: *R4 Repair leaflet*

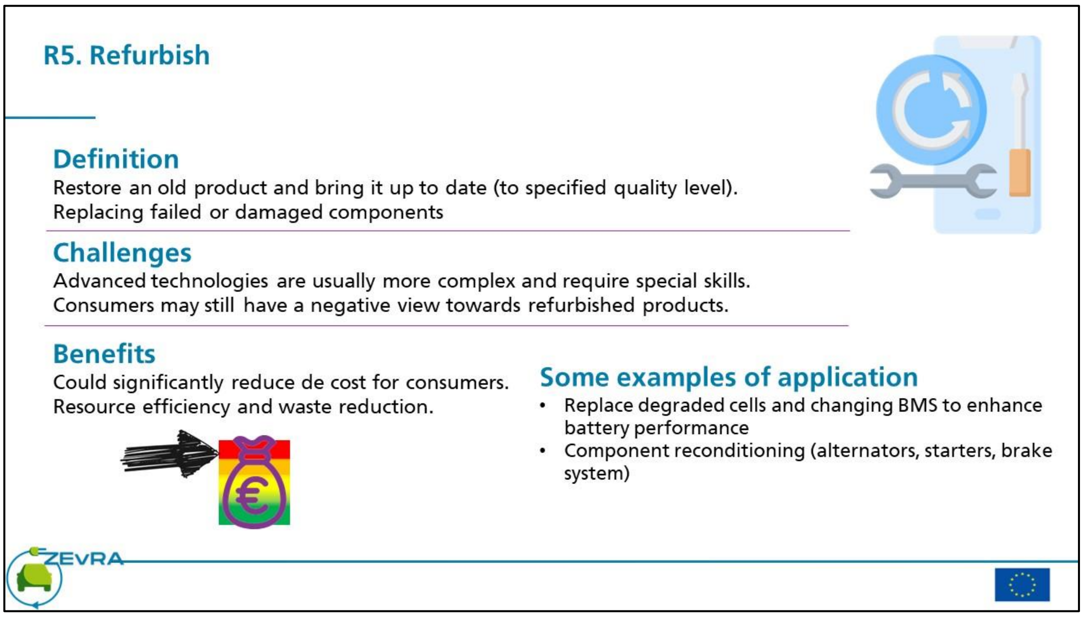

Figure 9: *R5 Refurbish leaflet*

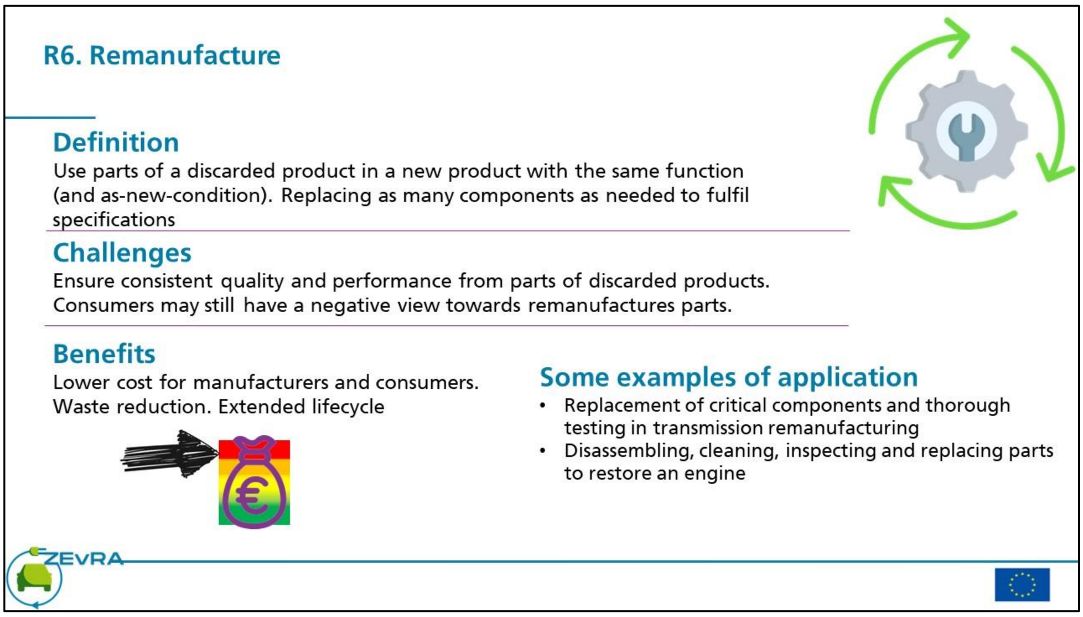

Figure 10: *R6 Remanufacture leaflet*

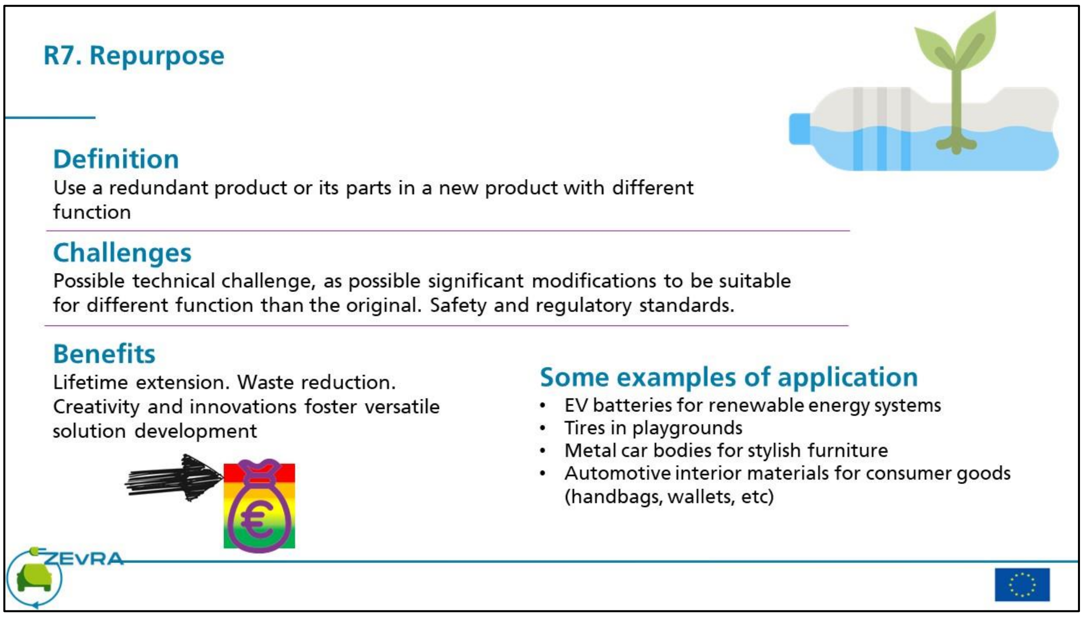

Figure 11: *R7 Repurpuse leaflet*

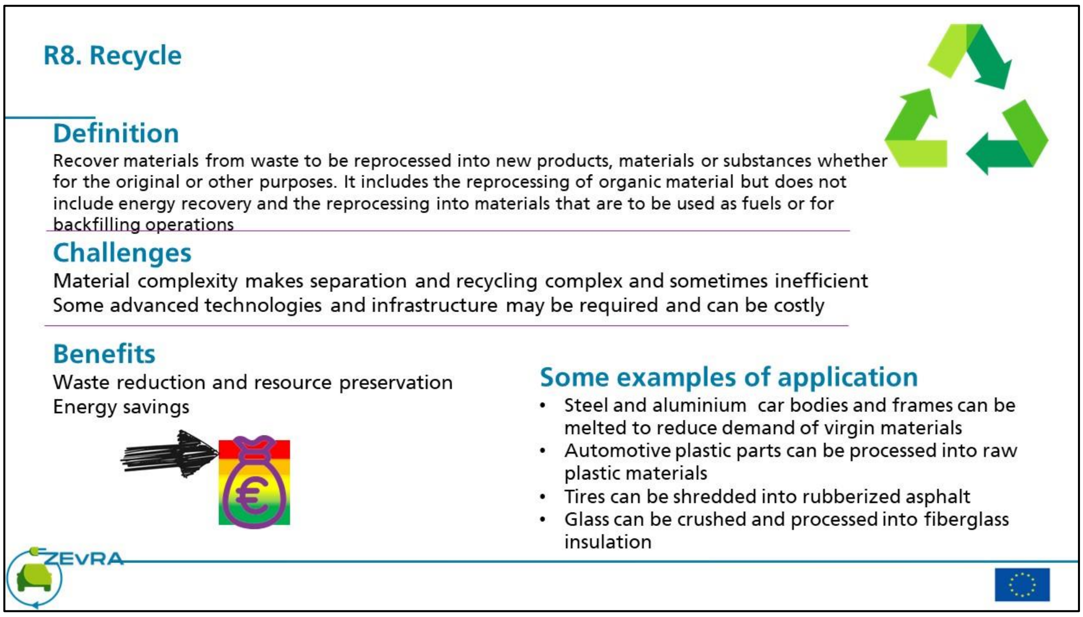

Figure 12: *R8 Recycle leaflet*

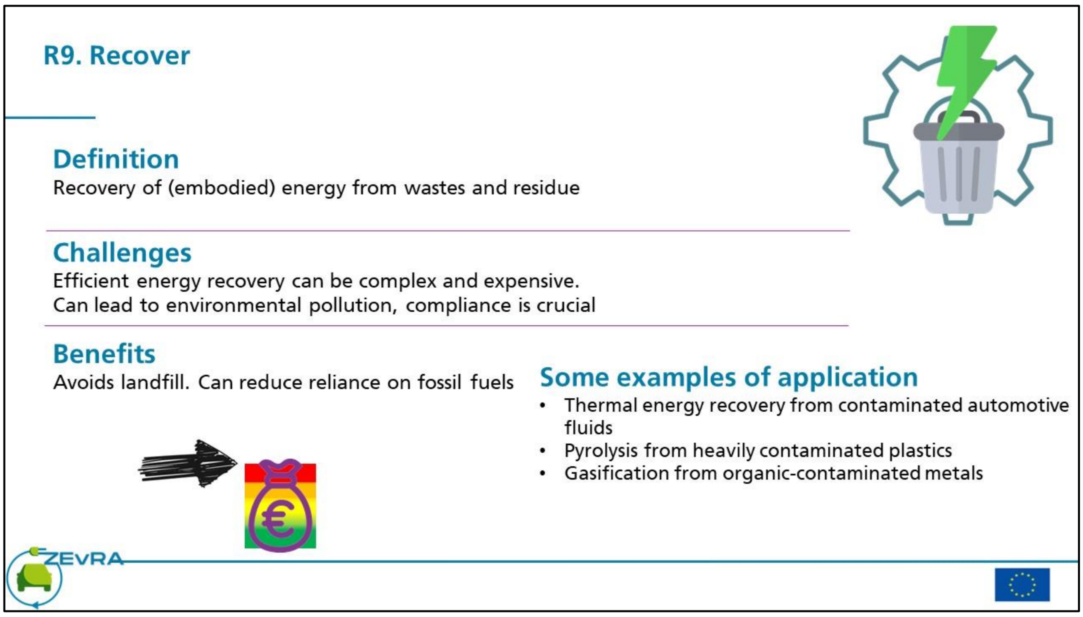

Figure 13: *R9 Recover leaflet*

The theoretical overview then was followed by a structured series of questions designed for the participants to share their expert view on the viability of implementing the 9Rs across different materials and components of EVs.

Questions were aimed at voting individually from 1-5 the feasibility of each of the different DfC strategies for each of the use cases of ZEvRA project. In order to make this voting process as practical and effective as possible, as well as easy to recover the results from it, the voting process was prepared online in Mentimeter platform, a few slides with the voting are presented in Figure 14, and link to access: https://www.menti.com/aluam9m8pr7w

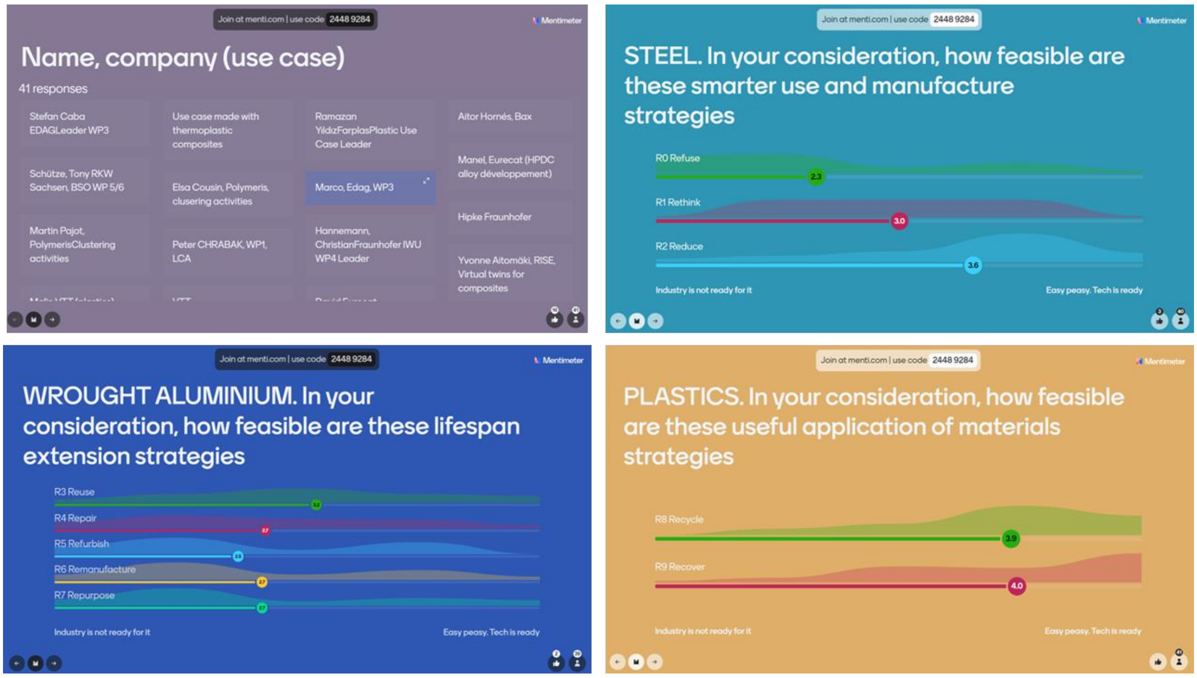

Figure 14: *Mentimeter screenshots*

Results from these questions per use case give insight into the viability of each of them.

Steel - Ranking:

1. R8 Recycle (4.38)
2. R2 Reduce (4)
3. R1 Rethink (3)
4. R3 Reuse (3)
5. R4 Repair (3)
6. R5 Refurbish (3)
7. R6 Remanufacture (3)
8. R7 Repurpose (3)
9. R9 Recover (2.51)
10. R0 Refuse (2)

R8 Recycling has been considered highly feasible by Main and Support partners during the workshop voting, most likely due to the well-established infrastructure and processes that efficiently recover steel from waste, making it a cost-effective and environmentally friendly option.

R2 Reducing its use is also considered as highly feasible, thought as a result of the advancements in engineering and design that nowadays allow to minimize steel requirements without compromising structural integrity and performance.

Contrariwise, R0 Refusing and R9 Recovery are considered less feasible, possibly due to steel's critical role in infrastructure and that there is no energy recovery from incinerating steel. The rest of strategies R1 within the smarter product use, and R3-R7 towards expanding the lifespan are considered moderately feasible, reflecting practical challenges in modifying existing products and processes.

Wrought Aluminium - Ranking:

1. R8 Recycle (4.28)
2. R2 Reduce (3.33)
3. R1 Rethink (2.92)
4. R3 Reuse (3.16)
5. R4 Repair (2.74)
6. R5 Refurbish (2.51)
7. R6 Remanufacture (2.71)
8. R7 Repurpose (2.71)
9. R9 Recover (2.36)
10. R0 Refuse (2.22)

R8 Recycle has been considered the most feasible option for wrought aluminium by Main and Support partners at the workshop voting, followed by R2 reducing its use are the most feasible strategies, with recycling being slightly more feasible. This can be explained by the mature recycling technology and high economic value of recycled aluminium, which consumes significantly less energy than primary production, around 90% less, according to European Aluminium Association [5], and even 95% less according to The World Counts.

DfC strategies R1 Rethinking and R3 Reusing pose a moderate feasibility according to partners, that can be attributed to the requirement of changes in design and use patterns, which can be practical but involve higher initial costs. R0 Refusing the use of wrought aluminium is considered less feasible, due to its essential presence in EV's and in respect to R9, that there is no energy recovery from incinerating aluminium. DfC lifespan extension strategies (R4 Repairing, R5 Refurbishing, R6 Remanufacturing, and R7 Repurposing) are considered with a lower feasibility, suggesting technical challenges and costs associated with extending the lifespan of wrought aluminium.

Casting Aluminium - Ranking:

1. R8 Recycle (4.36)
2. R2 Reduce (3.24)
3. R1 Rethink (2.82)
4. R3 Reuse (2.93)
5. R4 Repair (2.68)
6. R5 Refurbish (2.33)
7. R6 Remanufacture (2.74)
8. R7 Repurpose (2.33)
9. R9 Recover (2.33)

10. R0 Refuse (2.11)

Consistently, R8 Recycle, is considered the most feasible strategy, again, this can be explained by the mature recycling technology and high economic value of recycled aluminium, which consumes significantly less energy than primary production (around 90% less) [5].

R2 Reducing its use is the second most feasible DfC strategy, based most likely on lightweighting efforts as well as increased material (and cost) efficiency. Same as Wrought aluminium, DfC strategies R1 Rethinking and R3 Reusing pose a moderate feasibility due to the required changes in design and use patterns, which can be practical but involve higher initial costs. R0 Refusing the use of wrought aluminium is considered less feasible, due to its essential presence in EV's. DfC lifespan extension strategies (R4 Repairing, R5 Refurbishing, R6 Remanufacturing, and R7 Repurposing) are considered with a lower feasibility, suggesting technical and cost challenges.

Foam Aluminium - Ranking:

1. R8 Recycle (3.79)
2. R2 Reduce (3)
3. R1 Rethink (3.03)
4. R0 Refuse (2.56)
5. R3 Reuse (2.24)
6. R4 Repair (1.88)
7. R5 Refurbish (1.85)
8. R6 Remanufacture (1.90)
9. R7 Repurpose (2.20)

Continuing with aluminium, R8 Recycle, is considered the most feasible strategy, again, this can be explained by the mature recycling technology and high economic value of recycled aluminium, which consumes significantly less energy than primary production (around 90% less) [5]. All kinds of recycling aluminium can be used and processed to aluminium foam. A foam-to-foam version is also possible just reduced by some losses due to cleaning of oxides.

R2 Reducing its use is the second most feasible DfC strategy, attributed to lightweighting efforts as well as increased material (and cost) efficiency. DfC strategies R1 Rethinking, and R0 Refuse are considered with a moderate feasibility. Differently from the wrought and casting aluminium, foam aluminium can be considered to avoid its use, according to partners votes.

DfC lifespan extension strategies (R3 Reuse, R4 Repairing, R5 Refurbishing, R6 Remanufacturing, and R7 Repurposing) are considered with a lower feasibility, suggesting technical and cost challenges.

Plastics - Ranking:

1. R9 Recover (3.98)
2. R8 Recycle (3.93)
3. R2 Reduce (3.56)
4. R1 Rethink (3.34)
5. R3 Reuse (2.81)
6. R4 Repair (2.45)
7. R5 Refurbish (2.38)
8. R7 Repurpose (2.29)
9. R6 Remanufacture (2.10)
10. R0 Refuse (2.41)

Attributable to advancements in recycling technologies, growing economic incentives to recover plastic waste, as well as European regulatory incentives, R8 Recycling and R9 Recover are considered the most feasible DfC strategies.

R2 Reducing and R1 Rethinking are closely to the same feasibility considered for Recycling and recovering, thought as a result of increasing regulatory pressure and consumer demand for sustainable products.

Extending lifespan DfC strategies R3-R7 are considered to have a moderate-low feasibility, reflecting the possible challenges in maintaining the quality and integrity of plastics through multiple lifecycle stages. Refuse on the other hand is considered as the last of options, given the essential presence in EV's nowadays.

Composites - Ranking:

1. R2 Reduce (3.32)
2. R1 Rethink (3.03)
3. R8 Recycle (2.56)
4. R0 Refuse (2.44)
5. R4 Repair (2.38)
6. R3 Reuse (2.18)
7. R7 Repurpose (2.08)
8. R9 Recover (3.15)
9. R5 Refurbish (2)
10. R6 Remanufacture (1.90)

R2 Reducing use and R1 Rethinking are considered as the most feasible strategies for composites by the Main and Support partners, while R8 Recycle has moderate feasibility.

R0 Refusing composite use is considered less feasible, thought as a result of its high performance and specific applications. Lifespan extension DfC strategies R3-R7 are considered to have low to moderate feasibility, suggesting some challenges in maintaining the quality and integrity of composites after extending its use time. R9 Recover is still considered in a moderate to low feasibility for composites.

Glass - Ranking:

1. R8 Recycle (3.61)
2. R2 Reduce (2.67)
3. R1 Rethink (2.38)
4. R0 Refuse (2.18)
5. R3 Reuse (2.60)
6. R4 Repair (2.43)
7. R7 Repurpose (2.28)
8. R9 Recover (2.39)
9. R6 Remanufacture (1.98)
10. R5 Refurbish (1.70)

R8 Recycling is considered the most feasible DfC strategy, due to the straightforward and well-established recycling processes that maintain the material's quality. Although, the impurities and foreign substances in defected automotive glasses make it impossible to be used for producing automotive grade float glass but possible for products like bottles and glass containers which have lesser aesthetic sensitivity compared to automotive sector.

R2 Reducing glass use and R1 Rethinking its use are considered in a moderate-low feasibility driven by the possibilities of efficient design and substitution with other materials. Moreover, in terms of Rethinking, more sustainable opportunities arise to reduce water and coolant chemical usage when transitioning from standard glass cutting and grinding operations to laser cutting technology. On the other hand, R0 Refusing its use is considered less feasible, as glass is essential in many applications for its unique properties.

Lifespan extension strategies R3 -R7 are considered less feasible, attributable to the challenges in processing and maintaining the integrity of used glass. It is worth noting that glass can be reused only for aftermarket industry.

Tyres - Ranking:

1. R9 Recover (3.74)
2. R8 Recycle (3.41)
3. R2 Reduce (2.60)
4. R1 Rethink (2.45)
5. R3 Reuse (2.87)
6. R4 Repair (3.16)
7. R5 Refurbish (2.45)
8. R6 Remanufacture (2.34)
9. R7 Repurpose (2.82)
10. R0 Refuse (1.59)

R9 Recovering energy and R8 Recycle are considered the most feasible strategies, supported by mature technologies and high demand for recycled rubber products. R2 reducing its use and R1 Rethinking are also considered as feasible, presumably due to innovations in tyre design and materials.

Lifespan extension strategies R3-R7 are considered moderately feasible, reflecting ongoing efforts to extend tyre life and find secondary uses, though technical challenges and elevated costs can limit these options. Last option or least feasible is R0 Refuse strategy due to the critical role of tyres in transportation.

REE (Rare Earth Elements) - Ranking:

1. R8 Recycle (3.09)
2. R2 Reduce (2.84)
3. R1 Rethink (2.45)
4. R0 Refuse (2.32)
5. R3 Reuse (2.27)
6. R7 Repurpose (2.09)
7. R6 Remanufacture (2.03)
8. R5 Refurbish (1.94)
9. R4 Repair (1.82)
10. R9 Recover (1.85)

Highest feasibility is considered for R8 Recycle, thought as a result of the growing technological capabilities to recover rare earth elements from electronic waste and mostly driven by the high economic value of these materials.

Smarter use and manufacture DfC strategies (R2 reducing use, R1 Rethinking use and R0 Refusing its use) are considered moderate-low feasible, presumably driven by advancements in material science and design that can reduce dependence on rare earth elements, although refusing its use is possibly less feasible given the current dependence on REE in advanced technologies.

Lifespan extension strategies R3-R7 are considered to have a low feasibility, reflecting the significant technical challenges, the unawareness of the longer lifetime of magnets and their possibilities, along with the high costs associated with processing and reusing these materials.

3.2 Second Workshop: Brainstorming specific actions Workshop

Date: June 18th, 2024

Total of 53 participants (see Table *3*)

Table 3: *List of participants of the first workshop*

Number of Participants	Institution
2	Fraunhofer IWU
1	Northumbria UK
5	Eurecat
4	Bayzoltan
1	UNIBO IT
5	Skoda
3	Polymeris
2	RKW
1	RISE SE
1	Faurecia
2	EDAG DE
1	Raffmetal IT
2	TU Braunschweig DE
2	Farplas
2	Benteler
1	NTNU NO
1	APRA DE/BE
1	Endurance DE/IT
2	Volkswagen
1	Politecnico Milano IT
1	Continental
1	Sisecam
4	VTT
2	BaxCo
1	Toyota
3	Stellantis
1	CRF IT

A Brainstorming session was prepared for a first iteration of the definition of specific DfC actions for ZEvRA project. The session was prepared on an online known platform that allows all participants to add their ideas and see all the ideas presented from everybody on real-time. Platform that was used was MIRO and the link for it https://miro.com/app/board/uXjVK7jflSg=/, as well as the screenshots from the final platform in Figure 15.

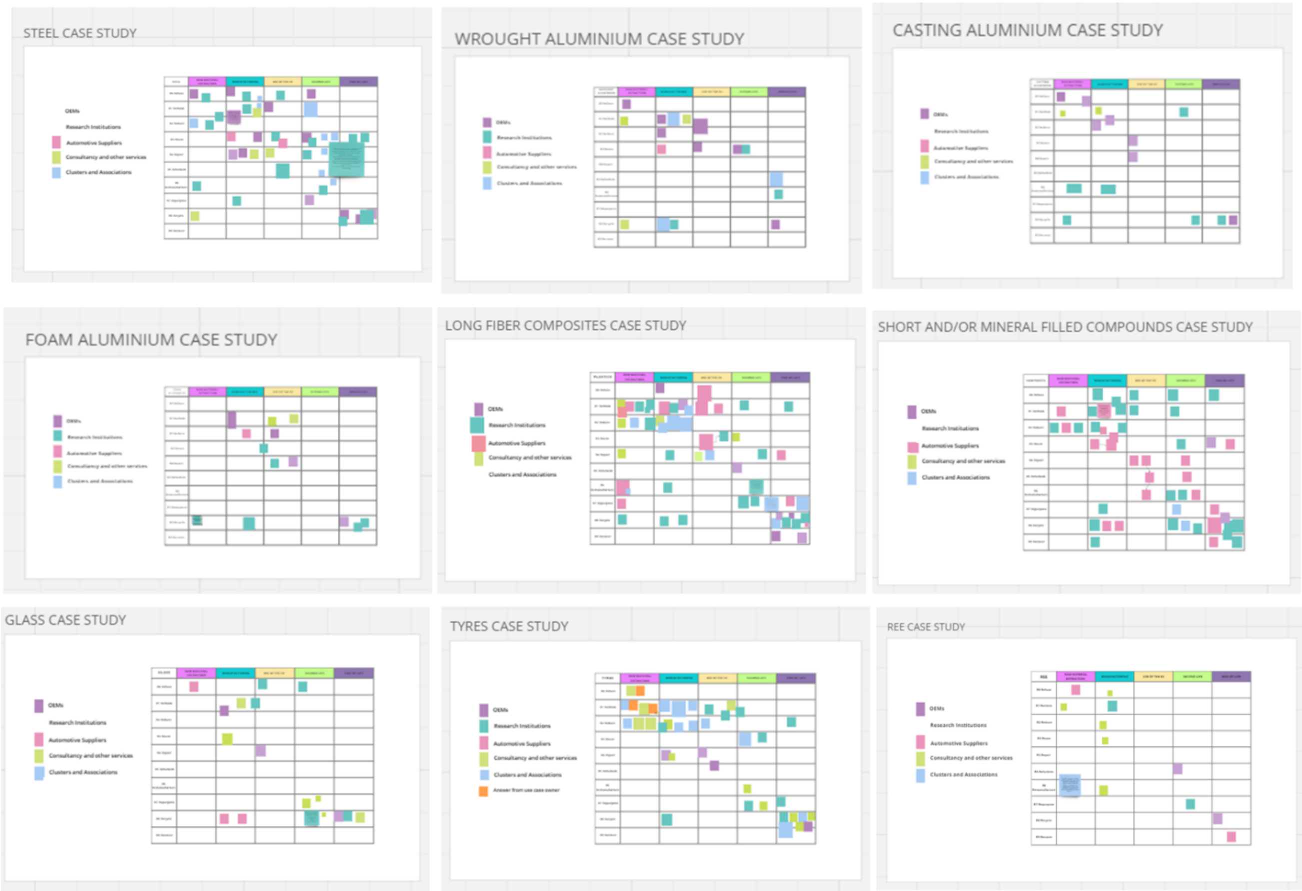

Figure 15: *MIRO platform screenshots from Brainstorming session*

In general, this brainstorming session explored all the different 9R strategies towards enhancing circularity in the automotive sector, particularly for the use cases in all the different life cycle stages. In Annex A all comments and ideas are presented. For an easier reading, contributors are identified with the following acronyms:

- OEM: Original Equipment Manufacturer
- RI: Research Institutions
- AS: Automotive Suppliers
- CY: Consultancy
- CA: Cluster Associations
- CO: Use case owner

From this full list we can extract some key ideas for each of the use cases:

Steel

Steel has been identified as a crucial material in EV's lifecycle. Discussions mainly centered on the reduction of the reliance on primary resources and instead incorporate more and more secondary materials. While, also optimizing the use through advanced design methodologies that enable its reuse, repair, recycling and following lives applications. **Table *4*** presents a summary of all the contributions regarding Steel in EVs.

Table 4: *Steel key ideas*

General strategy	DfC Key suggested actions
R0 Refuse	Manufacturing (OEM, CA, RI): Rethink steel's role, including the development of new applications. Use (RI): Design lighter vehicles that reduce the reliance on steel. Second Life (OEM): Use of secondary raw materials to increase sustainability.
R1 Rethink	Manufacturing (CA, RI, CY, OEM): Optimize/limit alloy mixes, and innovative designs to minimize material use. Educate designers and promote use of renewable energy in production. Use (OEM): High-strength steels for lightweight design improve EV efficiency and sustainability. Second Life (CA, RI): Offer community events to raise awareness. Collaboration throughout value chain for a cultural change
R2 Reduce	Raw Material Extraction (OEM, RI, CA): Focus on specific alloys to avoid rare elements. Use of improved extraction technologies (for first and secondary materials). Shift towards higher ratios of secondary raw materials to avoid primary extraction. Use: High-strength steels contribute to lightweight. Manufacturing (OEM): AI-driven design for material efficiency.
R3 Reuse	Manufacturing, Second Life (OEM, RI, AS): Modular structures and detachable joints facilitate reuse. Use (RI): New business models for legal bodies and individuals as well. End-of-Life (RI): Modular chassis structures could potentially be reused in next generation vehicles.
R4 Repair	Manufacturing (OEM, CY): Modular structures for improved repairability. Second Life (RI, CA): New business models including owner-repairable vehicles.
R5 Refurbish	Manufacturing (OEM, CA, RI): Design modular and/or simpler parts to enable refurbishment.
R6 Remanufacture	Raw Material Extraction (RI): Standardization in remanufacturing to reduce virgin material extraction. Second Life (RI, CA): Standardized designs to support remanufacturing.

General strategy	DfC Key suggested actions
R7 Repurpose	Second Life (OEM, RI): Sheet metal repurposed for new parts, including a further technological validation (corrosion and other aspects).
R8 Recycle	End-of-Life (OEM, RI): Steel is highly recyclable, uni-alloy designs would prevent downcycling.

Aluminium – Wrought

Ideas were more focused on reducing the reliance on raw material extraction, improving recycling routes, and making the material more reusable through smarter designs and circular business models, as it is summarized in Table 5.

Table 5: *Wrought aluminium key ideas*

General strategy	DfC Key suggested actions
R1 Rethink	Manufacturing (CA): Offer training to product designers.
R2 Reduce	Manufacturing (OEM): AI designs for efficient material use Use (OEM): Lightweight designs also improve energy efficiency during use stage.
R3 Reuse	Manufacturing, Use, Second Life (OEM, RI): Standardized components for easier reuse. Undamaged parts could be reused across different vehicles.
R5 Refurbish	Manufacturing, End-of-Life (OEM, CA): AI developed structures and cross-industry knowledge sharing throughout value chain to improve refurbishing practices.
R6 Remanufacture	End-of-Life (RI): New technologies for second-life aluminum forming
R8 Recycle	Raw Material Extraction (CY): Open new recycling routes for processed aluminum to increase availability of secondary material. End-of-Life (OEM, RI): Recycle is energy intensive. Scrap and chips to metal foam production before remelting.

Aluminium – Casting

Contributions targeted using scrap materials to reduce primary extraction, enhancing modularity for reuse and refurbishment, as well as promoting recycling and remanufacturing to close material loop. Table 6 presents collected key ideas for casting aluminium.

Table 6: *Casting aluminium key ideas*

General strategy	DfC Key suggested actions
R1 Rethink	Manufacturing (CY): Integrating parts into one to improve logistics while ensuring single-alloy components.

R2 Reduce	Manufacturing (OEM): AI and lightweight designs to optimize material use in casting. Joining technology to integrate components to structure.
R3 Reuse	Use (OEM): Offer robust quality assurance for structural parts.
R4 Repair	Use (OEM): Repair concepts to fix minor damages to a possible cast aluminium structure.
R6 Remanufacture	Manufacturing (RI): Standardization for remanufacturing plus additive technologies supporting reconditioning.
R8 Recycle	End-of-Life (OEM): Consider recycling aluminum scrap and chips into foam parts or reuse casting aluminum for new applications

Aluminium – Foam

It is evident from the contributions that foam aluminium presents unique challenges, particularly in regard to repairability, although at the same time it is a promising option for lightweight designs. Aluminium foams are also considered to have improved recycling routes. Table 7 presents the summarized results.

Table 7: *Foam Aluminium key ideas*

General strategy	DfC Key suggested actions
R0 Refuse	Manufacturing (OEM): AI-driven design for more efficient material use.
R1 Rethink	Manufacturing (OEM, CY): Suitable joining techniques to integrate foam aluminum parts. Use in smaller parts (wiper holder, ceiling handle holder…)
R2 Reduce	Manufacturing (AS): Compete with plastics in lightweight crash components.
R8 Recycle	End-of-Life (RI, OEM): Foam aluminum can be easily recycled, either into new foam or through serial process for shredding to powder

Long Fiber Composites (Plastics)

Contributions for this material were more focused on reducing raw material use, increasing recyclability, and promoting lightweight designs to enhance the material's and EV's lifecycle circularity. Results are summarized in Table 8.

Table 8: *Plastics key ideas*

General strategy	DfC Key suggested actions
R0 Refuse	Manufacturing (OEM, AS): Body panels that don't require painting, AI for effective design
R1 Rethink	Raw Material Extraction (CY, RI): Biobased matrices and higher quality polymers. Manufacturing (OEM, AS, CA): Reduce plastic variety, develop de-bond (adhesives) on command solutions Product passport
R2 Reduce	Manufacturing (CA, CY): Use scraps as input, digital tools/geometric design for increased efficiency in material use
R3 Reuse	Use(RI, AS): Reuse scrap to smaller parts. Standardize platforms to reuse components Second Life (CY): Switchable adhesives to recover parts
R4 Repair	Raw Material Extraction (CY, CA) Self-healing materials development. Use (CA, CY) auto-repairing e.g. vitrimers
R5 Refurbish	Manufacturing (OEM): AI for effective design
R6 Remanufacture	Raw Material Extraction (AS): Use of composite parts from other industries (wind/aero) Manufacturing (RI): 3D printing for automated remanufacturing
R7 Repurpose	End-of-Life (CA, AS): Use non recyclables in other industries at EoL, as well as bigger parts to produce smaller parts Second Life (RI): Digital tools to identify stored parts and most appropriate application
R8 Recycle	Raw Material Extraction (OEM): mono-material solutions End-of-Life (RI): More efficient collection, sorting and recycling technologies, development of lower cost chemical recycling methods for long fibers and mechanical recycling for composites.
R9 Recover	Manufacturing (OEM): Recover energy from materials that couldn't reach a higher circularity management

Short and/or Mineral Filled Compounds (Composites)

Inputs during the session were more focused on the need for innovative design and secondly on recycling methods that reach higher levels of circularity. Reducing the complexity and variety of materials, as well as integrating bio-based alternatives can increase the sustainability of composite materials. It's highlighted that there is a need for more efficient and sustainable recycling alternatives, as it is seen on Table 9.

Table 9: *Composites key ideas*

General strategy	DfC Key suggested actions
R1 Rethink	Raw Material Extraction (RI, AS): Mono-material surfaces plus bonus system to encourage this practices, use of postindustrial thermoplastic composite scrap.
R2 Reduce	Raw Material Extraction (RI, AS): Bio-based alternatives as well as secondary raw materials. Old Glass fibers as PCR content in injection molding Manufacturing (RI, AS): Use a combination of particle, extrusion and injection molding foaming for better performance (density, quality). Chemical and physical foaming for lightweight solutions
R3 Reuse	Manufacturing (AS): Prioritize reusing auxiliary components from older parts, such as over-engineered plastic clips, and used them multiple times due to their durability. End-of-Life (OEM): Dismantling as repair for other EVs
R4 Repair	Use (AS): Consider repair for valuable parts (e.g. spoilers instrument panel components and structural components)
R6 Remanufacture	Manufacturing (IT): Standardize design to facilitate reuse and remanufacture Second Life (RI): Design for disassembly
R7 Repurpose	Manufacturing (RI): Offer plastics as feedstock for 3D printing components Second Life (CA): Allow downcycling
R8 Recycle	Manufacturing (RI, AS): Good quality post-industrial scrap and the reduced use of additives can increase recyclability and recycled content End-of-Life (OEM, AS): Design for dismantling to enhance recyclability
R9 Recover	End-of-Life (RI): Energy recovery/pyrolysis/solvent-based depolymerization after n cycles of recycling

Glass

Contributions for this use case focused on opportunities on refusing and rethinking the use of glass to increase its circularity, while the use of AI in design is also seen as a profitable approach to design more efficiently glass components as well as for repurposing them for other industries. Recycling within EVs use is considered challenging although could be used for lower quality requirement glass. Table 10 presents the main contributions for glass.

Table 10: *Glass key ideas*

General strategy	DfC Key suggested actions
R0 Refuse	Raw Material Extraction (AS): Glass can be replaced by thermoplastics with less CO2 footprint Use (RI): Cameras to replace glass
R1 Rethink	Manufacturing (CY, RI): Renewable energy in manufacturing. Thermal and sound isolation glass

R2 Reduce	Manufacturing (OEM): AI to reduce thickness and increase material consumption efficiency
R3 Reuse	Manufacturing (CY): Standardization of smaller windows and mirrors
R4 Repair	Use (OEM): Repair damaged glass w/o cutting it out
R6 Remanufacture	Manufacturing (OEM): AI to efficiently remanufacture glass components
R7 Repurpose	Second Life (CY): Glass parts as substrate for solar panels. Small components from bigger ones
R8 Recycle	Manufacturing (AS): Recycle into lower grades for darkened glass End-of-Life (RI, CY): Production for other industries with lower quality requirements e.g. packaging, glass fiber.

Tyres

Brainstorming highlighted key ideas like manufacturing tyres using bio-based and recycled materials, optimizing tyre design for easier repair and recycling, and developing remanufacturing and repurposing methods. Table 11 presents a summarized set of ideas.

Table 11: *Tyres key ideas*

General strategy	DfC Key suggested actions
R0 Refuse	Raw Material Extraction (CY, CO): Natural based rubber and recycled natural rubber (not yet available) to reduce raw material extraction
R1 Rethink	Raw Material Extraction (CA, CY, CO): Development of bio-based fillers. Thicker product is discouraged due to less efficiency during use stage. Manufacturing (CA): Design better sorting at EoL. Design to facilitate repair Use (RI): Modular design by layers to allow partly substitution
R2 Reduce	Raw Material Extraction (CA, CY): Reduction of additives and fillers. Manufacturing (CA, CY, RI): Reduction of wheel dimensions.
R3 Reuse	Second Life (RI): Clear information for users on appropriate use.
R4 Repair	Manufacturing (CA): Design to facilitate repair also at vehicle production stage, with extended possibilities of repair for minor damages
R5 Refurbish	Manufacturing (OEM): AI for efficient design and resource use. Use (OEM): Using protectors instead of new tyres
R6 Remanufacture	Second Life (RI): Restore the surface
R7 Repurpose	End-of-Life (RI): Use as fillers or isolation for buildings. Second Life (RI, CY): Use tyres as fillers in roads or other purposes
R8 Recycle	End-of-Life (CY, CA): Facilitate recycling through simplified chemistries or easy separation of layers

General strategy	DfC Key suggested actions
R9 Recover	Manufacturing (CA): Optimize vulcanization process and re-use thermal energy. End-of-Life (RI): Pyrolysis of rubber and recovery of oils

REE

Inputs for REE were more limited than the rest of use cases. Main contributions lead to the use of advanced carbon materials to replace REE, while strategies like reuse and remanufacturing are considered also feasible, although possibly requiring participation from all stakeholders to standardize models that support the process. Table 12 presents main ideas for more circular REE components.

Table 12: *REE key ideas*

General strategy	DfC Key suggested actions
R0 Refuse	Raw Material Extraction (AS): Use of Carbon materials as substitutes. Manufacturing (CY): REE-less electric drives
R1 Rethink	Raw Material Extraction (RI): Consider other elements
R2 Reduce	Manufacturing (CY): More efficient processing
R3 Reuse	Manufacturing (CY): Standardized system for electric drives to allow their reuse in the next generation of products
R4 Repair	Manufacturing (OEM): AI to define the best fate and efficient use of resources
R6 Remanufacture	Raw Material Extraction (CA): Design for disassembly and change of business model
R9 Recover	Manufacturing (OEM): AI to define the best fate and efficient use of resources

4 Final Remarks

The two workshops results finalize the first iteration of the DfC Methodology, with results for the third (Re-adaption of Technological Procedures to Selected Strategies) and forth (Selection of Concrete DfC Actions and Conceptualized Design) steps, evaluating the viability of the different strategies for ZEvRA use cases and giving a first approximation to the specific actions that could take place for each of the use cases.

First workshop highlighted R8 Recycling as the most feasible strategy across nearly all materials, mainly due to the well-established recycling technologies at the moment, offering cost-effective alternatives, especially for steel and aluminium, even though it's important to remember that while recycling is effective, it should be seen as one of the last resorts in circular economy. Lower Rs are more desirable as they promote smarter design that minimizes material use and extends the lifespan of products. Particularly R2 Reduce has been voted as highly feasible for many materials, supported specially by innovative design. Contrarily, lifespan extension strategies (R4 Repair, R5 Refurbish and R6 Remanufacture) have been considered less viable, mainly due to technical and cost related challenges, more specially for complex materials like plastics, composites and REE. R0 Refuse has been consistently ranked low, as these materials (use cases) can be essential in various applications.

Second workshop provided valuable insights towards the definition of the specific DfC actions for ZEvRA use cases. Key ideas included modularity, design for disassembly, and the integration of AI for material optimization and end-of-life management.

Steel. More secondary materials and modular design for a better reuse and recycling alternatives. Community engagement along the value chain has been also considered relevant.

Aluminium. Use of fewer different alloys to enhance recycling sorting and impurities. Enhancing Material consumption reduction through lightweight design and new advanced technologies. Second life applications have been also considered.

Plastics and composites. Compostable plastics and a reduction in the complexity in material classes. Standardize designs and improved recycling technologies while also considering new business models for reuse and remanufacture involving community engagement.

Glass. Replacing glass with thermoplastics and AI for a more efficient design. Repurposing glass for other industries has also been proposed.

Tyres. Biobased materials, repairability and improved recycling techniques. Repurposing tyres for building insulation or fillers on roads.

REE. Explore carbon-based materials and standardize REE materials and solutions.

In general, most popular contributions include:

- The use of AI to reach better levels of efficiency in use of materials, and also for more circular designs and end-of-life solutions.
- Standardization in design and material class to increase reuse and recycling.
- Increase secondary material content to reduce reliance on primary raw materials.

Ideas presented during both workshops will lay the groundwork for next iterations of DfC in EVs.

5 References

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[5] European Aluminium Association. The aluminium content in cars grows every year thanks to its properties that make it appealing for car manufacturers 2022.

6 Annex

MATERIAL CASE STUDY	R#	STAGE	STAKEHOLDERS	PROPOSED ACTION
STEEL	R0 Refuse	RAW MATERIAL EXTRACTION	OEM	If there would be enough material for recycling/reusing, we potentially could stop using raw materials
STEEL	R0 Refuse	MANUFACTURING	OEM	Reduce the number of different alloys in the vehicle.
STEEL	R0 Refuse	USE OF THE EV	RI	Lightweight design don't count on steel during operation
STEEL	R0 Refuse	SECOND LIFE	OEM	Can help to safe costs
STEEL	R0 Refuse	RAW MATERIAL EXTRACTION	RI	Using a higher ratio of secondary raw materials would spare the use of primary resources
STEEL	R0 Refuse	MANUFACTURING	CA	Education in design process to refuse steel
STEEL	R0 Refuse	MANUFACTURING	RI	Produced with renewable energy (electricity)
STEEL	R1 Rethink	MANUFACTURING	CA	Education in design process to rethink steel
STEEL	R1 Rethink	USE OF THE EV	OEM	Advanced high strength steels for lightweight design increase energy efficiency
STEEL	R1 Rethink	SECOND LIFE	CA	Offer Information events or Workshops to the Community (Tony Schütze / RKW Sachsen)
STEEL	R1 Rethink	MANUFACTURING	RI	Invent new application of material
STEEL	R1 Rethink	MANUFACTURING	CY	It will be necessary to rethink the mix of different strength of the steel, to get a better circularity for the future.
STEEL	R1 Rethink	MANUFACTURING	OEM	change the design to use less material
STEEL	R2 Reduce	RAW MATERIAL EXTRACTION	RI	Use and developed specific alloys for specific uses in the car (avoiding the use of the most rare elements as most as possible.
STEEL	R2 Reduce	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
STEEL	R2 Reduce	RAW MATERIAL EXTRACTION	CA	Info and awareness events in design process, educate consumers to reduce steel use

STEEL	R2 Reduce	RAW MATERIAL EXTRACTION	RI	With more efficient extraction technology of raw materials, both for primary and secondary material flows. This opinion valid for the other material flows.
STEEL	R3 Reuse	MANUFACTURING	AS	I believe direct reuse are limited to movable components as body in white or structural sections need to be r4 5 or 6
STEEL	R3 Reuse	USE OF THE EV	RI	New business modell for EVs, as product as a service not only for legal bodies, but for individuals. This opinion valid for the other material flows.
STEEL	R3 Reuse	SECOND LIFE	OEM	Modular vehicle structure enables reuse concepts not only on raw material level
STEEL	R3 Reuse	END-OF-LIFE	RI	Modular chassis structures ready fir next generation vehicles (the problem is that this will cut the evolution of vehicles)
STEEL	R3 Reuse	MANUFACTURING	OEM	Design for dismantling --> detachable joining technologies
STEEL	R3 Reuse	USE OF THE EV	AS	Good point : rented car or shared car (instead of individual car) : car that is sturdy and easy to clean, durability will be even more important instead of fancy and fragile surfaces
STEEL	R3 Reuse	SECOND LIFE	CA	Rise awareness in consumers
STEEL	R3 Reuse	END-OF-LIFE	RI	New tec should be implemented
STEEL	R3 Reuse	SECOND LIFE	CA	New business models to enhance second lifes/circularity, e.g. product as a service, owner can reuse
STEEL	R3 Reuse	SECOND LIFE	RI	Ok to reuse
STEEL	R4 Repair	MANUFACTURING	OEM	Modular structure for simplified repairability
STEEL	R4 Repair	USE OF THE EV	CY	With new high strength steels also light wwight are available
STEEL	R4 Repair	SECOND LIFE	CA	New business models to enhance second lifes/circularity, e.g. product as a service, owner can repair
STEEL	R4 Repair	MANUFACTURING	CY	It is easy to repair and the tools are for everyone useful.

STEEL	R4 Repair	SECOND LIFE	RI	Repairing easy by welding if not coating therefore able for second life
STEEL	R4 Repair	MANUFACTURING	OEM	There are processes to repair steel parts
STEEL	R5 Refurbish	MANUFACTURING	THEIR	Design parts not vopinionible such they due standartopinioned and can be reused c other cars
STEEL	R5 Refurbish	USE OF THE EV	RI	Could be a viable option in case of EVs due to their simpler structure comparing to ICE cars. This opinion valid for the other material flows.
STEEL	R5 Refurbish	SECOND LIFE	CA	New business models to enhance second lifes/circularity, e.g. product as a service, owner can refurbish
STEEL	R6 Remanufacture	RAW MATERIAL EXTRACTION	RI	Standardized approach to steel remanufacturing would reduce virgin extraction
STEEL	R6 Remanufacture	SECOND LIFE	CA	New business models to enhance second lifes/circularity, e.g. product as a service, owner can remanufacture
STEEL	R6 Remanufacture	END-OF-LIFE	RI	R3-R8: The systemic change for prolonging life time and optimizing recycling technologies needs collaboration between actors in the value chain, as well as technology development and cultural change. Second life + End of Life. Design interactions include choosing materials and manufacturing methods that support easy disassembly, standardized design models and materials , as well as collaboration of design with other value chain actors to ensure R3-R8 is feasible and economically solid. This is not case specific - it covers all components of the automotive.
STEEL	R6 Remanufacture	SECOND LIFE	RI	Design rules for parts for a second life
STEEL	R7 Repurpose	MANUFACTURING	RI	OK to repurpose
STEEL	R7 Repurpose	SECOND LIFE	OEM	Possible to use sheet metal as new input for new parts. Needs to be checked in terms of technology still / corrosion resistance, …
STEEL	R8 Recycle	RAW MATERIAL EXTRACTION	CY	Every where is much metal available so it will be possible to reduce the amount of raw material.
STEEL	R8 Recycle	END-OF-LIFE	OEM	Steel is easy to recycle and technology is prepared for it
STEEL	R8 Recycle	END-OF-LIFE	OEM	Steel is ok to recycle

STEEL	R8 Recycle	END-OF-LIFE	RI	The more strict legal inventory on EoL cars, where they are exported and how this process could be more legitim. This opinion valid for the other material flows.
STEEL	R8 Recycle	END-OF-LIFE	OEM	Uni-alloy concepts for better recycling (no downcycling)
STEEL	R8 Recycle	END-OF-LIFE	RI	Use post consumer scrap as well as others to
STEEL	R9 Recover	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
WROUGHT ALUMINIUM	R0 Refuse	RAW MATERIAL EXTRACTION	OEM	If there would be enough material coming out of recycling, we could stop using row material
WROUGHT ALUMINIUM	R1 Rethink	RAW MATERIAL EXTRACTION	CY	If there is no low alloy recyclate available - maybe it is time to start a new recycling route refining aluminum and maybe recovering the alloying elements
WROUGHT ALUMINIUM	R1 Rethink	MANUFACTURING	CA	Offer learning nuggets for Product designers RKW Sachsen
WROUGHT ALUMINIUM	R1 Rethink	USE OF THE EV	OEM	If we would use less material, the consumption of energy from batteries could be smaller, we could have bigger ranges
WROUGHT ALUMINIUM	R1 Rethink	MANUFACTURING	OEM	Obviously, there is always potential to change the design and save some sources
WROUGHT ALUMINIUM	R1 Rethink	MANUFACTURING	CY	Combination of many single parts into one will helps to reduce the logistic.
WROUGHT ALUMINIUM	R2 Reduce	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
WROUGHT ALUMINIUM	R3 Reuse	MANUFACTURING	AS	Design parts not visible such they are standardized and can be reused in other cars
WROUGHT ALUMINIUM	R3 Reuse	USE OF THE EV	OEM	If you have damaged something on your vehicle, you could buy some used components which are good as new (if you have rear crash, vehicle is KO, but frontend is still usable)
WROUGHT ALUMINIUM	R3 Reuse	SECOND LIFE	OEM	If the part is not damaged, we could use it in another car. the separation from older cars needs to be organized, the market is nor prepared yet
WROUGHT ALUMINIUM	R3 Reuse	SECOND LIFE	RI	Developed Al-structures that detect impacts and giving feedback of potential reuse (worse case=easy to recycle as same material class)

WROUGHT ALUMINIUM	R4 Repair	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
WROUGHT ALUMINIUM	R5 Refurbish	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
WROUGHT ALUMINIUM	R5 Refurbish	END-OF-LIFE	CA	Connect with Car dismantling companies to share experience RKW Sachsen
WROUGHT ALUMINIUM	R6 Remanufacture	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
WROUGHT ALUMINIUM	R6 Remanufacture	END-OF-LIFE	RI	Develop technologies for a second forming after the use
WROUGHT ALUMINIUM	R7 Repurpose	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
WROUGHT ALUMINIUM	R8 Recycle	RAW MATERIAL EXTRACTION	CY	New circuit routes must be opened in order to obtain sufficient processed material
WROUGHT ALUMINIUM	R8 Recycle	MANUFACTURING	CA	Support producers via Workshops to sensibilize the workers to the importance of leftovers and recycling RKW Sachsen
WROUGHT ALUMINIUM	R8 Recycle	END-OF-LIFE	OEM	This consumes lot of energy, but we have to deal with end of life alu and use it again
WROUGHT ALUMINIUM	R8 Recycle	MANUFACTURING	RI	Recycle all production scrap and machining chips to metal foam production instead of remelting
WROUGHT ALUMINIUM	R9 Recover	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
CASTING ALUMINIUM	R0 Refuse	RAW MATERIAL EXTRACTION	OEM	Using enough scrap material
CASTING ALUMINIUM	R0 Refuse	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
CASTING ALUMINIUM	R0 Refuse	RAW MATERIAL EXTRACTION	OEM	Using of scrap over new raw material (target to do as much as technologically feasible)

CASTING ALUMINIUM	R1 Rethink	RAW MATERIAL EXTRACTION	CY	Establish a new raw material extraction route starting at alloys and leading to pure aluminum (not the bauxite route)
CASTING ALUMINIUM	R1 Rethink	MANUFACTURING	CY	Integrate different parts into one to achieve same Material - Mega casting Approach
CASTING ALUMINIUM	R1 Rethink	SECOND LIFE	RI	Giving the material second life and use in another application if possible
CASTING ALUMINIUM	R2 Reduce	MANUFACTURING	OEM	Joining technology to integrate cast aluminium components to the structure
CASTING ALUMINIUM	R2 Reduce	MANUFACTURING	OEM	Designs according to weight savings
CASTING ALUMINIUM	R3 Reuse	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
CASTING ALUMINIUM	R3 Reuse	USE OF THE EV	OEM	Quality assurance before reusing structural parts
CASTING ALUMINIUM	R4 Repair	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
CASTING ALUMINIUM	R4 Repair	USE OF THE EV	OEM	Repair concepts to fix minor damages to a possible cast aluminium structure
CASTING ALUMINIUM	R5 Refurbish	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
CASTING ALUMINIUM	R6 Remanufacture	RAW MATERIAL EXTRACTION	RI	Standardized approach to reman cast AL will save energy from extraction and manufacturing. Additive technologies can support in the reconditioning.
CASTING ALUMINIUM	R6 Remanufacture	MANUFACTURING	RI	Standardized approach to reman cast AL will save energy from extraction and manufacturing. Additive technologies can support in the reconditioning.
CASTING ALUMINIUM	R7 Repurpose	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
CASTING ALUMINIUM	R8 Recycle	RAW MATERIAL EXTRACTION	RI	Well established and easy to use

CASTING ALUMINIUM	R8 Recycle	SECOND LIFE	RI	Good joining methods are necessary to put it out
CASTING ALUMINIUM	R8 Recycle	END-OF-LIFE	RI	We frscture all types of Al and create foam parts out of it. Especially hard to recycle otherwise parts or chips.
CASTING ALUMINIUM	R8 Recycle	END-OF-LIFE	OEM	Recycle and use the material again
CASTING ALUMINIUM	R9 Recover	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
FOAM ALUMINIUM	R0 Refuse	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
FOAM ALUMINIUM	R1 Rethink	MANUFACTURING	OEM	Find suitable joining technologies to integrate foamed aluminium parts
FOAM ALUMINIUM	R1 Rethink	USE OF THE EV	CY	For profiles wit
FOAM ALUMINIUM	R1 Rethink	MANUFACTURING	OEM	Using foam we can use less material in structural parts
FOAM ALUMINIUM	R1 Rethink	USE OF THE EV	CY	Use in smaller, maybe not so obvious applications e.g. Wiper holder or Ceiling Handle holder
FOAM ALUMINIUM	R2 Reduce	MANUFACTURING	AS	Even compete with plastics in terms of lightweighting structural crash or rear components for example impact absorbers
FOAM ALUMINIUM	R2 Reduce	USE OF THE EV	OEM	Getting closer to lightweight vehicles
FOAM ALUMINIUM	R3 Reuse	MANUFACTURING	RI	Lightweight because of the lower use o material
FOAM ALUMINIUM	R4 Repair	MANUFACTURING	POSSIBILITY	Design parts not vRlible such they changed standartRled and can be reused in other cars
FOAM ALUMINIUM	R4 Repair	USE OF THE EV	OEM	Construction of parts that in case of damage they can be easily changed - no possibility to repair the alu foam part itself?
FOAM ALUMINIUM	R4 Repair	USE OF THE EV	RI	Uncertainties regarding repairability of foam structures

FOAM ALUMINIUM	R5 Refurbish	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
FOAM ALUMINIUM	R6 Remanufacture	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
FOAM ALUMINIUM	R7 Repurpose	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
FOAM ALUMINIUM	R8 Recycle	RAW MATERIAL EXTRACTION	RI	easy to achieve as foam to foam is possible or all Al-scrap to foam
FOAM ALUMINIUM	R8 Recycle	MANUFACTURING	RI	Serial process for shredding aluminium foam to powder
FOAM ALUMINIUM	R8 Recycle	END-OF-LIFE	OEM	Possibility to recycle the material in the end. put the foam aloy into aloy construction, not into steel
FOAM ALUMINIUM	R8 Recycle	END-OF-LIFE	RI	Serial process for shredding aluminium foam to powder
FOAM ALUMINIUM	R8 Recycle	END-OF-LIFE	RI	Work foam to foam…easy recycling
FOAM ALUMINIUM	R9 Recover	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
LONG FIBER COMPOSITES (PLASTICS)	R0 Refuse	MANUFACTURING	OEM	Reduce the number of different plastics in the vehicle
LONG FIBER COMPOSITES (PLASTICS)	R0 Refuse	USE OF THE EV	AS	No more painting of car body : exposed textured mass colored TPC parts for body panels
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	RAW MATERIAL EXTRACTION	CY	Development of biobased matrices
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	MANUFACTURING	OEM	Use only one material in production of the parts, to give it recyclability in the end of life

LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	USE OF THE EV	AS	Replace metal parts by TPC for to reduce car weight (battery housings, seat structures,)
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	SECOND LIFE	RI	Use durable, high quality polymers and fibres that allow an extended life allowing product to be used again
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	END-OF-LIFE	RI	Change of ownership so components are owned and leased (eg. battery box lid or whole container)
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	RAW MATERIAL EXTRACTION	RI	Using natural fibres instead of synthetic fibers
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	MANUFACTURING	AS	Develop debond on command solutions for adhesive bondin of dissimilar materials (metal/TPC)
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	USE OF THE EV	AS	Interior parts for shared cars without soft surfaces for more strudy parts that are easy to clean
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	RAW MATERIAL EXTRACTION	AS	Use of plastics from packaging as a source for matrix in TPC
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	MANUFACTURING	RI	Integration of body and shell proporties in a integral component
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	RAW MATERIAL EXTRACTION	RI	Use and recycle biobased polymer

LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	MANUFACTURING	CA	Work on separation fiber and organic matrix
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	RAW MATERIAL EXTRACTION	AS	Digital passport in the TPC part to make esaier the RX in the future
LONG FIBER COMPOSITES (PLASTICS)	R1 Rethink	RAW MATERIAL EXTRACTION	RI	Use basalt fibres instead of glass
LONG FIBER COMPOSITES (PLASTICS)	R2 Reduce	RAW MATERIAL EXTRACTION	CA	Provide info on material properties of recyclates
LONG FIBER COMPOSITES (PLASTICS)	R2 Reduce	MANUFACTURING	CY	Using all Cut-offs for generating Injection molding granulates
LONG FIBER COMPOSITES (PLASTICS)	R2 Reduce	RAW MATERIAL EXTRACTION	RI	Using load-path adpated technologies on high volume production machinery for providing better fiber utilization and better lightweight performance
LONG FIBER COMPOSITES (PLASTICS)	R2 Reduce	MANUFACTURING	CA	Use of digital tools for using less materials
LONG FIBER COMPOSITES (PLASTICS)	R2 Reduce	RAW MATERIAL EXTRACTION	CY	Use of old parts as feedstock
LONG FIBER COMPOSITES (PLASTICS)	R2 Reduce	MANUFACTURING	CA	Reuduce the amont of raw materials thank's to geometric design

LONG FIBER COMPOSITES (PLASTICS)	R2 Reduce	MANUFACTURING	CA	Promote lightweight technologies among SMs and include OEMs as customers
LONG FIBER COMPOSITES (PLASTICS)	R3 Reuse	MANUFACTURING	REUSE	Design parts not vhousingible such they standards standarthousinged and can be reused da other cars
LONG FIBER COMPOSITES (PLASTICS)	R3 Reuse	USE OF THE EV	RI	Reuse of components in standardized plattforms or sregulated standards
LONG FIBER COMPOSITES (PLASTICS)	R3 Reuse	SECOND LIFE	CY	Use of switchable Adhesives to recover the parts
LONG FIBER COMPOSITES (PLASTICS)	R3 Reuse	USE OF THE EV	AS	Reuse cut offs to mold smaller parts (battery housing cut off to make small lid)
LONG FIBER COMPOSITES (PLASTICS)	R4 Repair	RAW MATERIAL EXTRACTION	CY	Self-healing materials development
LONG FIBER COMPOSITES (PLASTICS)	R4 Repair	MANUFACTURING	RI	Repair of composite structures
LONG FIBER COMPOSITES (PLASTICS)	R4 Repair	USE OF THE EV	CA	Auto-repairing
LONG FIBER COMPOSITES (PLASTICS)	R4 Repair	SECOND LIFE	RI	Repair components by future to develop in mold chemical solvolyse and reinjection

LONG FIBER COMPOSITES (PLASTICS)	R4 Repair	END-OF-LIFE	AS	Dismantle part and make a new molding cycle to repair part
LONG FIBER COMPOSITES (PLASTICS)	R4 Repair	USE OF THE EV	CY	Repair solution for composite part as part of the concept - use of vitrimers (e.g. https://www.comppair.ch/),https://www.comppair.ch/, https://www.comppair.ch/
LONG FIBER COMPOSITES (PLASTICS)	R4 Repair	SECOND LIFE	OEM	possibilities for refurbishing plastic parts - holding up the high standarts
LONG FIBER COMPOSITES (PLASTICS)	R5 Refurbish	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
LONG FIBER COMPOSITES (PLASTICS)	R6 Remanufacture	RAW MATERIAL EXTRACTION	AS	Use thermoplastic composite parts of other industries (wind/aero) to manufacture new automotive parts
LONG FIBER COMPOSITES (PLASTICS)	R6 Remanufacture	MANUFACTURING	RI	3D Printing for repair and reburbishment for automated remanufacturing of battery lid
LONG FIBER COMPOSITES (PLASTICS)	R6 Remanufacture	SECOND LIFE	RI	Creating technologies for remanufacturing
LONG FIBER COMPOSITES (PLASTICS)	R6 Remanufacture	RAW MATERIAL EXTRACTION	CA	Good point, but more repurposing than remanufacturing
LONG FIBER COMPOSITES (PLASTICS)	R7 Repurpose	RAW MATERIAL EXTRACTION	AS	Recover fibres from textiles as reinforcements, compensate quality variations by higher design strength

LONG FIBER COMPOSITES (PLASTICS)	R7 Repurpose	SECOND LIFE	RI	Secondlife uses for thermoplastic composites (by means of thermoforming): paddle racket, sport guards (shin, masks, etc), etc.
LONG FIBER COMPOSITES (PLASTICS)	R7 Repurpose	END-OF-LIFE	CA	Use of non-recyclable composites for other application (furniture?)
LONG FIBER COMPOSITES (PLASTICS)	R7 Repurpose	SECOND LIFE	RI	Digital tools therefor; identifing the right part in a storage for the right new application
LONG FIBER COMPOSITES (PLASTICS)	R7 Repurpose	END-OF-LIFE	AS	Cut large pieces of TPC battery partt as raw material for new parts (like steel roof to fender)
LONG FIBER COMPOSITES (PLASTICS)	R7 Repurpose	END-OF-LIFE	CA	Use of fiber (downcycling) for building
LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	RAW MATERIAL EXTRACTION	RI	Reduce virgin fiber use for new composites
LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	MANUFACTURING	RI	Use chemical recycle of wind turbine long fibre for source of discontinous fibre flakes. Create a TP SMC
LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	END-OF-LIFE	OEM	New technologies for recycling needed - accessible chem. recycling, new mechanical recycling methods
LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	MANUFACTURING	RI	Mechanical recycling of composites

LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	END-OF-LIFE	OEM	Mono-material approach to simplify recycling without down-cycling
LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	END-OF-LIFE	RI	Chemical technologies not developed enought to achieve long fibre recovery (excesive cost)
LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	END-OF-LIFE	RI	The most easy and already in practice, however the collection of EoL vehicles is still a challenge even in Western-Europe. This statement is valid for aluminium as well.
LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	END-OF-LIFE	CA	Increase the number of cycles in recycling
LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	END-OF-LIFE	RI	Better schredding technologies with filters needed for better material separation for recycling in short-fiber processes or remelting glass fibers
LONG FIBER COMPOSITES (PLASTICS)	R8 Recycle	END-OF-LIFE	AS	Recover materials with shorter fibres and use it for short fibre use case
LONG FIBER COMPOSITES (PLASTICS)	R9 Recover	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
LONG FIBER COMPOSITES (PLASTICS)	R9 Recover	END-OF-LIFE	OEM	We can still get some energy from end of life material - for example generate heat of electricity
LONG FIBER COMPOSITES (PLASTICS)	R9 Recover	END-OF-LIFE	OEM	What to do with the rest of the material, that is not possible to recycle?

SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R0 Refuse	MANUFACTURING	RI	Refuse to recycle or incineration of good quality plastic parts and aim for reusing
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R0 Refuse	USE OF THE EV	RI	Interieur could bei AR and only virtuell; the overall interieur could be a mono material ground surface
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R0 Refuse	SECOND LIFE	RI	Refuse to recycle or incineration of good quality plastic parts and aim for reusing
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R0 Refuse	END-OF-LIFE	RI	Refuse to recycle or incineration of good quality plastic parts and aim for reusing
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R0 Refuse	MANUFACTURING	RI	Integration of so far separated materials for safeing effort for disassembly and better performance utilization
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R1 Rethink	RAW MATERIAL EXTRACTION	AS	Use short fiber reinforced plastics that come from shredded thermoplastic composite parts (postindustrial or ELV)
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R1 Rethink	MANUFACTURING	AS	Avoid design of parts that are multilayer of different materials that cannot be seperated

SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R1 Rethink	USE OF THE EV	RI	Reduce quality expections for better circularity and safe necessary fiber or additives
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R1 Rethink	SECOND LIFE	RI	Focus on using standard polymer types for non-visable part- some sort of bonus system (EU level?) for use of standard type
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R1 Rethink	MANUFACTURING	RI	Shortfibre/mineral composites can be subtituted by a monomaterial? if yes go ahead
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R1 Rethink	MANUFACTURING	RI	Design phase has the utmost importance to offer potentially viable contributions to the circularity at each life cycle stages. Once we have the option to intervene in a process it means less cost and higher freedom in implementation. However, the feedback to the design phase from consecutive life cycle stages is also crucial to realise real circularity and mitigate the dependency of EU on CRMs and other relevant material flows. This opinion is general and supposed to be valid for the other material flows.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R2 Reduce	RAW MATERIAL EXTRACTION	RI	Using biobased sources eben for creating established types of plastics
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R2 Reduce	MANUFACTURING	RI	Reduce weight by using gradient of density through combination of particle, extrusion and injection molding foaming; Provide better surface quality by variothermal proceses

SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R2 Reduce	RAW MATERIAL EXTRACTION	AS	Bio-based alternatives and using secondary raw materials are penetrating to market fast
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R2 Reduce	MANUFACTURING	RI	Aim design for recycling and high performance (strong material) at the same time to reduce the material amount in plastic part
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R2 Reduce	RAW MATERIAL EXTRACTION	RI	Use filtered old and used Glasfibers and reuse them as PCR content in Injection Molding
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R2 Reduce	MANUFACTURING	AS	Design for Circularity to reduce the use of extra materials and allowing lightweight manufacturing
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R2 Reduce	MANUFACTURING	AS	Chemical and physical foaming in injection molding have been proven to be realistic for lightweighting plastic components
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R3 Reuse	MANUFACTURING	AS	In manufacturing phase focus must be on using auxiliary components from older parts so that we can utilize at least few plastics more than one time.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R3 Reuse	SECOND LIFE	RI	Reduce small changes in desgin of non-visable plastic parts

SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R3 Reuse	END-OF-LIFE	OEM	After EOL not damaged parts should be dismanteled from the vehicles to use for repairs of other cars
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R3 Reuse	MANUFACTURING	AS	Good example could be using plastic clips from older parts as these components usually over-engineered and have a extended use than usual.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R3 Reuse	END-OF-LIFE	AS	Plastics do not usually find a secondary use as it is easier to produce new parts then dismantling and using it all over again
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R4 Repair	USE OF THE EV	AS	Only valid for complex and valuable parts such as spoilers instrument panel components and structural components but still very limited.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R4 Repair	SECOND LIFE	AS	Usualyy goes to recycling or inciniration second life is limited for few components
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R4 Repair	USE OF THE EV	AS	Defective parts do not usually find possibility of second use as it is easier to make new parts and low embedded value on various plastic parts.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R5 Refurbish	MANUFACTURING	IT	Design parts not vlowible such they use standartlowed and can be reused ll other cars

SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R5 Refurbish	USE OF THE EV	AS	Defective parts do not usually find possibility of second use as it is easier to make new parts and low embedded value on various plastic parts.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R5 Refurbish	SECOND LIFE	AS	Usualyy goes to recycling or inciniration second life is limited for few components
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R6 Remanufacture	MANUFACTURING	IT	Design parts not vlowible such they use standartlowed and can be reused ll other cars
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R6 Remanufacture	USE OF THE EV	AS	Defective parts do not usually find possibility of second use as it is easier to make new parts and low embedded value on various plastic parts.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R6 Remanufacture	SECOND LIFE	RI	Design for non-destructive disassembly
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R6 Remanufacture	SECOND LIFE	AS	Usualyy goes to recycling or inciniration second life is limited for few components
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R6 Remanufacture	SECOND LIFE	RI	Reforming used materials; Research on extending usability of the materials for different production cycles

SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R7 Repurpose	MANUFACTURING	RI	After treatment of EoL plastics, it can be repurposed as feedstock in 3D printing that would be used in manufacturing
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R7 Repurpose	SECOND LIFE	CA	Allow the supply of used plastics in upper segment usage (aerospace or defense industry) and make a down-cycling, which can provide standard properties for automotive.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R7 Repurpose	END-OF-LIFE	AS	It is common to use plastics for another purpose after end of life however it usually diminishes the value of materials due to the insufficient mixing and low performance characteristics
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	MANUFACTURING	RI	Good quality post industrial waste can be used during manufacturing
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	SECOND LIFE	RI	Plastic parts that are in their second lives can be recycled to aim for use in the same application or upcycling/downcycling
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	END-OF-LIFE	OEM	Cars should not be shredered as a hole at their EOL
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	MANUFACTURING	AS	Using recycled additives

SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	SECOND LIFE	CA	New and advanced recycling procedures to separate purely the polymers/plastics and additives without any degradation.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	END-OF-LIFE	AS	Dismantle car to separate plastic parts as much as possible (avoid grinding complete car)
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	MANUFACTURING	AS	It has major importance of the way towards recycling as additives and minor ingredients can interfere with recyclability of plastics. Material producers should focus on simpler formulations for the sake of the second life of plastics.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	SECOND LIFE	RI	Reducing of material mix are necessary for a better recycle possibility
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	END-OF-LIFE	RI	It has limited recyclability (mechanical recycling) ín terms of number of recycling cycles. The reason is grinding of short fibers. Mineral filled compounds have more recyclability.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	END-OF-LIFE	RI	Materialclustering of assemblys for better separation of cheap materials
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R8 Recycle	END-OF-LIFE	RI	Non-profitability of recycling process

SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R9 Recover	MANUFACTURING	RI	Searching new technologies for new and green energy resources to recycle (both additives and polymers)
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R9 Recover	END-OF-LIFE	RI	After n number of cycles of short fiber reinforced compounds, the reinforcing function reduces substantially. After this, the better option is either energy recovery strategy or pyrolysis or solvent-based depolymerization depending on the feedstock. If the compound is polyolefin-rich (at least ~85%), then it can be pyrolysed if the material doesn't contain too much metal. If the polymer is PET or polyamide (for example) it can go through solvent based depolymerization (which is a type of chemical recycling). In solvent based chemical recycling fiber recovery is possible.
SHORT AND/OR MINERAL FILLED COMPOUNDS (COMPOSITES)	R9 Recover	END-OF-LIFE	AS	Worst choice among others for plastics as we are completely destroying the valuable materials with little energy. Thermal processes are only 40% efficient at most. Recovery should not be encouraged.
GLASS	R0 Refuse	RAW MATERIAL EXTRACTION	AS	High engineering thermoplastics can replace some glass use as generates lower CO2 make it greener
GLASS	R0 Refuse	USE OF THE EV	RI	Why glass? Use cameras?
GLASS	R0 Refuse	SECOND LIFE	RI	Not applicable for same purpose but for different application
GLASS	R1 Rethink	MANUFACTURING	CY	Making manufacturing processes usable using less energy or renewable energy in order to optimize this use case
GLASS	R1 Rethink	MANUFACTURING	RI	Thermal and soiund isolation glasses
GLASS	R2 Reduce	MANUFACTURING	OEM	Rethink the thickness?
GLASS	R3 Reuse	MANUFACTURING	CY	Standardization for smaller windows and mirrors
GLASS	R4 Repair	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
GLASS	R4 Repair	USE OF THE EV	OEM	Change of a damaged glas without cutting it out of the car

GLASS	R5 Refurbish	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
GLASS	R6 Remanufacture	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
GLASS	R7 Repurpose	SECOND LIFE	CY	Use of all glass parts as substrate for Solar Panels - not for vehicles but for buildings,etc.
GLASS	R7 Repurpose	SECOND LIFE	CY	Production of the very small glass parts using old large glasses (door window to CD-Pillar Window)
GLASS	R8 Recycle	MANUFACTURING	AS	For darkend / privicy glass lower glass quality might be sufficient as lower requirements on view might be existing
GLASS	R8 Recycle	SECOND LIFE	RI	Use the glass material as raw material in other applications
GLASS	R8 Recycle	END-OF-LIFE	OEM	Using glas from EOL in other products possible? to aim at usability of the material outside of the closed loop
GLASS	R8 Recycle	MANUFACTURING	AS	Downcycling! it is not recyclable as we think
GLASS	R8 Recycle	SECOND LIFE	CY	Recycling for applications where the glass does not need to be 100% translucent - laboratory equipment e.g.
GLASS	R8 Recycle	END-OF-LIFE	RI	Producing other glass products out of recycled glass from automotive. For example glass fiber. Other applications where optical properties are not needed can be also possible.
GLASS	R8 Recycle	END-OF-LIFE	CY	The demands on glass in cars are so high that recycling it only makes sense for alternative things. For example, packaging material such as bottles etc.
GLASS	R9 Recover	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
TYRES	R0 Refuse	RAW MATERIAL EXTRACTION	CY	The use of natural based rubber
TYRES	R0 Refuse	RAW MATERIAL EXTRACTION	CO	Recycled alternative for natural rubber is looked out, but not yet available

TYRES	R1 Rethink	RAW MATERIAL EXTRACTION	CA	Use bio-fillers if possible
TYRES	R1 Rethink	MANUFACTURING	CA	Think to the separation at the end life
TYRES	R1 Rethink	USE OF THE EV	CY	In addition to reusing old material for new tires, optimizing the processing of old tires would serve to further conserve resources. Development of longer-lasting tires may come at the expense of safety, as the increase in hardness reduces adhesion properties.
TYRES	R1 Rethink	SECOND LIFE	RI	Sensors and algorithms for estimation of remaining useful life
TYRES	R1 Rethink	RAW MATERIAL EXTRACTION	CO	1st products available on the market with bio based fillers e.g. Rice Husks
TYRES	R1 Rethink	MANUFACTURING	CA	Facilitate de repairing of the side of tyre
TYRES	R1 Rethink	USE OF THE EV	RI	Modular design: substitution of surface layer once lifespan arrives
TYRES	R1 Rethink	RAW MATERIAL EXTRACTION	CY	Thicker tyres enabling reconstructing the design after certain wear
TYRES	R1 Rethink	MANUFACTURING	CA	Optimise vulcanisation process and re-use thermal energy
TYRES	R1 Rethink	USE OF THE EV	RI	Increase lifespan (new compounds?)
TYRES	R1 Rethink	RAW MATERIAL EXTRACTION	CO	Will lead to higher rolling resitance and therefore higher energy need during service life
TYRES	R2 Reduce	RAW MATERIAL EXTRACTION	CY	Dev. Airless tyres
TYRES	R2 Reduce	MANUFACTURING	CY	Smaller wheel diameter
TYRES	R2 Reduce	USE OF THE EV	CA	Carefully about the increasing degradation of tyre with electric vehicle because of the power of the engine
TYRES	R2 Reduce	END-OF-LIFE	RI	Pyrolysis of rubber and recovery of oils
TYRES	R2 Reduce	RAW MATERIAL EXTRACTION	CY	Reduce additives
TYRES	R2 Reduce	MANUFACTURING	CA	Try tu reduce the number of components taking the same mechanical properties

TYRES	R2 Reduce	RAW MATERIAL EXTRACTION	CA	Reduce raw material
TYRES	R2 Reduce	MANUFACTURING	RI	Reduce width of tyre as just for optical purpose not for application needs
TYRES	R2 Reduce	MANUFACTURING	CA	Reduce fillers in the formulation
TYRES	R3 Reuse	SECOND LIFE	CA	Find valorisation issues
TYRES	R3 Reuse	SECOND LIFE	RI	Use of retread tyres specifically for low milage trailer - may be done already! Clear information to customers on appropriate use and potentially subsidised
TYRES	R4 Repair	MANUFACTURING	OEM	No possibility to reapair a tyre in case of damage in the production process of a car
TYRES	R4 Repair	USE OF THE EV	OEM	Possibilities to repair a puncture / minor damage
TYRES	R4 Repair	MANUFACTURING	CY	This is about possibilities not about reasons not to do anything
TYRES	R5 Refurbish	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
TYRES	R5 Refurbish	USE OF THE EV	OEM	Use protectors instead of using new tyres (as on trucks)
TYRES	R6 Remanufacture	SECOND LIFE	CY	Defined Reman-Process restaurating the surface
TYRES	R7 Repurpose	SECOND LIFE	RI	Could be interesting to see some design products from EoL tyres
TYRES	R7 Repurpose	END-OF-LIFE	RI	Fillers or isolation for buildings?
TYRES	R7 Repurpose	SECOND LIFE	CY	Used tyres as fillers in roads or other locations (if chemistry is more env. friendly, repurposing is easier)
TYRES	R8 Recycle	MANUFACTURING	RI	Support producers by identifying and connecting to best fitting recycling-opportunities
TYRES	R8 Recycle	END-OF-LIFE	RI	Find other applications for rubber materials
TYRES	R8 Recycle	END-OF-LIFE	CA	Work on devulcanisation process economically effeiciency
TYRES	R8 Recycle	END-OF-LIFE	CY	New Process Peeling the textiles out of the tyre
TYRES	R8 Recycle	END-OF-LIFE	CY	Clear recycling route for carbon black, pyrolysis oil and steel
TYRES	R8 Recycle	END-OF-LIFE	OEM	Recycle as much as possible
TYRES	R8 Recycle	END-OF-LIFE	CA	Developpment of coating easy to disassemble (textile-rubber, steel-rubber)

TYRES	R8 Recycle	END-OF-LIFE	CY	Simplify the chemistry of tyres (homogenisation), facilitate the recycling
TYRES	R9 Recover	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
REE	R0 Refuse	RAW MATERIAL EXTRACTION	AS	Advanced carbon materials such as graphene, carbon nanotubes, carbon nano-onions, carbon nano-buds, footballene, etc. have a huge potential to replace rare elements in terms of electrical electronical applications , anode and cathode development, sensor development, battery and other electronic medias
REE	R0 Refuse	MANUFACTURING	CY	Use of REE-less electric drives
REE	R1 Rethink	RAW MATERIAL EXTRACTION	CY	Use of Samarium instead of Neodymium for Drives
REE	R1 Rethink	MANUFACTURING	RI	Go over to another elements
REE	R2 Reduce	MANUFACTURING	CY	High accuracy in manufacturing to achieve same performance with less material
REE	R3 Reuse	MANUFACTURING	CY	Standardized System for Drives to enable reuse in the next generation
REE	R4 Repair	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
REE	R5 Refurbish	SECOND LIFE	OEM	Bringing back not damaged parts with REE for car repairs
REE	R6 Remanufacture	RAW MATERIAL EXTRACTION	CA	R6 for all cases: In order to simplify remanufacturing, it must already be considered in the design process (disassembly, cleaning, ...), but also in the development of the business model (who remanufactures?, who is responsible for the return logistics?, ...).
REE	R6 Remanufacture	MANUFACTURING	CY	Reman for all electric drives - including smaller ones for lifting the trunk door etc.
REE	R7 Repurpose	SECOND LIFE	RI	Find solutions to use magnets a second time
REE	R8 Recycle	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
REE	R8 Recycle	END-OF-LIFE	OEM	Recovering of the REE at their EOL - new afordable technologies
REE	R9 Recover	MANUFACTURING	OEM	Using AI to design the most effective design of the component so we could use less material
REE	R9 Recover	END-OF-LIFE	AS	We are incinerating lots of valuable complex components which comprise of ree and lost the value forever. New tech needed to extract such material from their carrying medias.

