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# Zero Emission electric Vehicles enabled by haRmonised circularity

**Deliverable 1.2**

# Preliminary definition of the Circularity assessment

**28th June 2024**

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ZEvRA
Zero Emission electric Vehicles enabled by haRmonised circulArity

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# Document history

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| 30 April 2024 | V1 | Initial draft for internal (EUT) revision |
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| 07 January 2025 | V4 | Revised version 1 |

  

## 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.

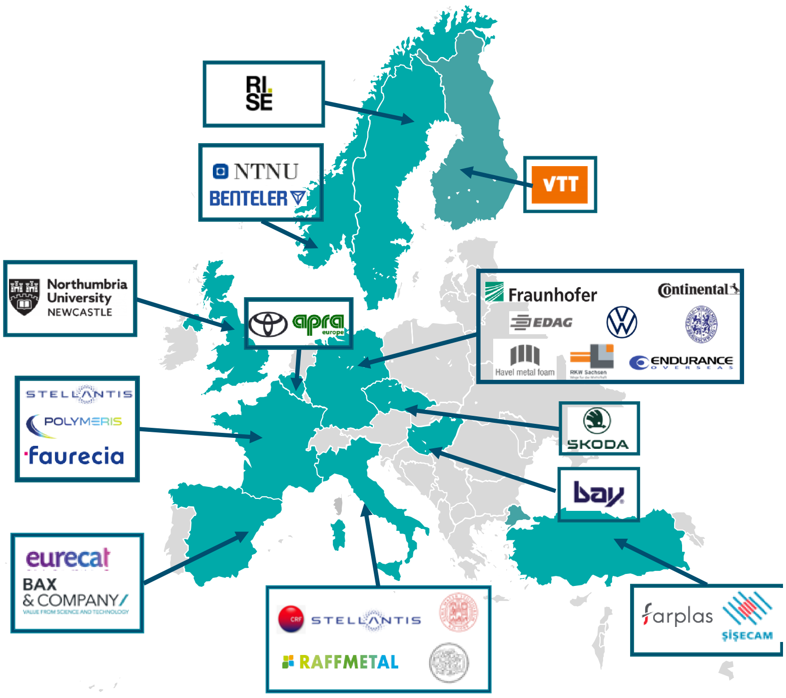


***Figure 1** ZEvRA Consortium*

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 |
|---|---|
| HCA | Harmonised Circularity Assessment |
| CEES | circular, environmental, economic and social spheres |
| LCSA | Life Cycle Sustainability |
| LCA | Life Cycle Assessment |
| LCC | Life Cycle Costing |
| SLCA | Social Life Cycle Assessment |
| EoL | End of Life |

# Executive summary

Given the pressing need to address environmental challenges and promoting sustainability, circular economy has risen as a crucial strategy. The 9R framework, provides a comprehensive approach to implementing circular economy practices in various industries. Moreover, given the automotive industry's significant role in the global economy and its major contribution to environmental impacts due to its resource-intensive manufacturing processes and high levels of waste generation, embracing circular economy principles, particularly the 9R framework, becomes essential for reducing the automotive industry's footprint.

This deliverable introduces the Harmonised Circularity Assessment (HCA) developed by EURECAT to assess circularity at the product level. The HCA-tool aggregates circular, environmental, economic and social spheres' indicators (CEES-indicators; a preliminary list is given in this document), to obtain a final numerical value, which enables a benchmarking exercise among the evaluated products. This holistic life cycle sustainability assessment extends beyond environmental concerns, encompassing a broader sustainability perspective.

The key point of HCA is data transformation, which entails converting a raw data source, the CEES-indicators values for each of the products analysed, into a ready-to-use format which enables their processing and integration. This conversion process involves a polarity transformation followed by a scaling process and a rating process. Through a standardize evaluation and comparison of alternatives, the HCA-tool serves as a critical decision-support tool to enhance circular performance-based strategies.

The application of the HCA methodology in ZEVRA's solutions can greatly contribute to reducing their environmental impact, promote sustainability and align these solutions with circular economy goals. This deliverable describes in detail the methodological framework and implementation plan for the HCA-tool, emphasizing its sustainability benefits within the automotive industry.

  

# 1 Introduction

Circular economy has become an essential concept in addressing pressing environmental challenges and promoting sustainability [1]. The 9R framework [2] which includes the principles of refuse, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle, and recover (see Figure 2), provides a comprehensive approach to implementing circular economy practices in various industries.

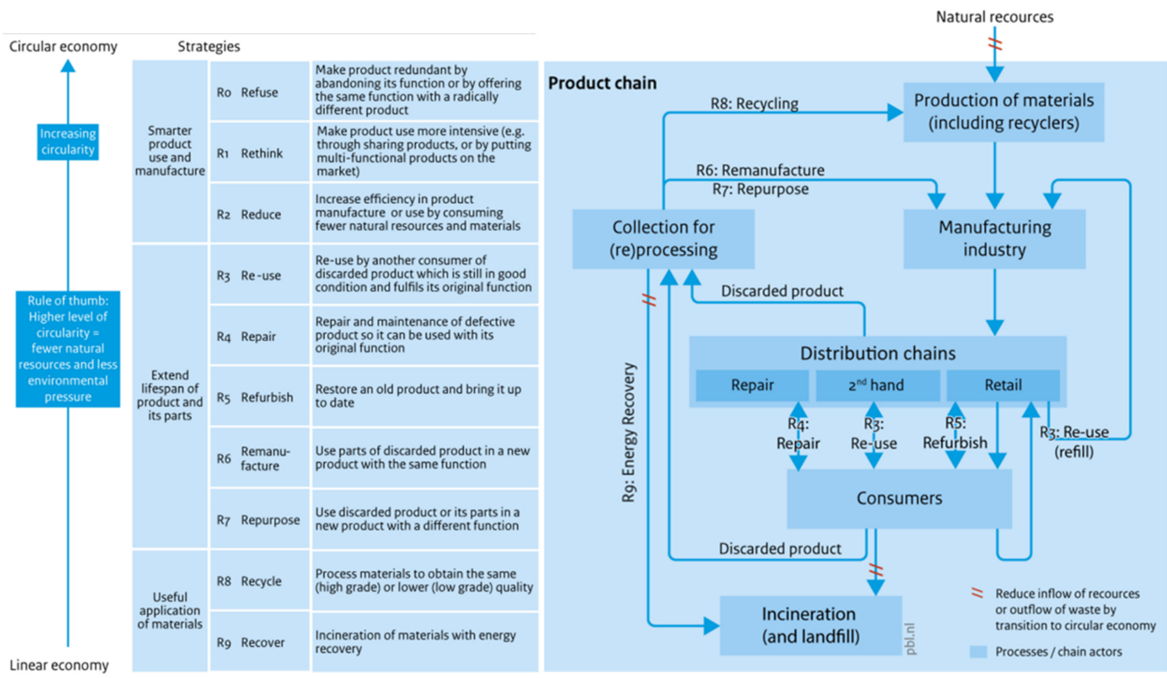


***Figure 2*** *9R framework circularity strategies and the role of actors in the production chain. Source: PBL Netherlands Environmental Assessment Agency (modified).*

The automotive industry plays a significant role in the global economy and is a major contributor to environmental impacts due to its resource-intensive manufacturing processes and high levels of waste generation [3,4]. Embracing circular economy principles, particularly the 9R framework, in the car industry is essential for reducing its environmental footprint and promoting sustainability to lead to improved resource efficiency and waste reduction by promoting the reuse of materials, components, and products, as well as reducing the demand for virgin resources during the manufacturing, use, and end-of-life stages of vehicles.

Actions in this line may result in economic benefits by creating new economic opportunities for the car industry, such as the development of remanufacturing and recycling facilities, as well as the establishment of new business models centred on product longevity and resource efficiency (thus transitioning to a circular economy model), and in the mitigation of the environmental impact of vehicle manufacturing and disposal by promoting the efficient use of resources and minimizing pollution.

# 2 Harmonised Circularity Assessment – Methodology

Sustainability assessments have broadened from merely environmental concern to a holistic life cycle sustainability assessment. The Harmonised Circularity Assessment (HCA) developed by EURECAT is devoted to assessing circularity at the product level (intermediate and/or final) thus helping industries/companies decision-making from an eco-design perspective. The HCA-tool aggregates circular, environmental, economic and social spheres' indicators (from now CEES-indicators, see Figure 3), to obtain a final numerical value, single-indicator, which enables a benchmarking exercise among the evaluated products. In essence, the HCA-tool enables the standardize evaluation and comparison of products, making it a useful decision-tool for supporting circular performance-based strategies.


***Figure 3:*** *Conceptual infographic of the Harmonised Circularity Assessment*

## 2.1 Single-indicator, simplifying the complexity

One of the strong points of the HCA-methodology is the single-indicator role, which enables products' harmonised circularity performance comparisons at a glance (with values from 1 to 0, being 1 the most sustainable product among the compared; see Figure 4 and Figure 5).


***Figure 4*** *Mock-up of the Harmonised Circularity Assessment disaggregated results 1/2*

However, although well received by some stakeholders because of its simplicity, the opposite is also true for the same reason. Indeed, in the recently published document Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on substantiation and communication of explicit environmental claims (Green Claims Directive), although oriented to labelling schemes, warns about the use of rating or score based on an aggregated indicator: "There is a risk that the nature of an aggregate indicator could be used to dilute negative impacts of certain parameters of the product with more positive impacts of other parameters and transmit misleading information to the consumer regarding the actual main impacts of the product". Thus, to prevent its simplicity from becoming a weak point, the HCA also offers a sphere-per-sphere report which deconstruct the single-indicator to deeper understand its inner composition structure.

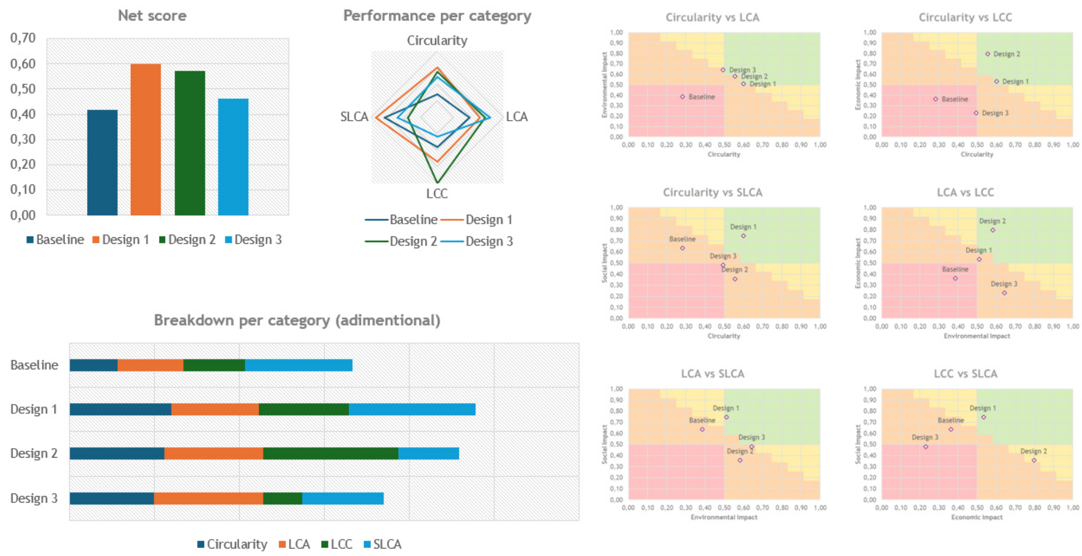


***Figure 5:*** *Mock-up of the Harmonised Circularity Assessment disaggregated results 2/2*

## 2.2 Mathematical procedure

The HCA is based on data transformation, the process of converting data from one format or structure into another. The process involves converting a raw data source, the CEES-indicators, into a ready-to-use format which enables their processing and integration. In the case of the HCA-tool, which is based in a Life Cycle Sustainability tool (LCSA-tool) developed by EURECAT, the data transformation involves the conversion of the CEES-indicators into compatible data which can be integrated into a single indicator (see Figure 6).

### 2.2.1 Data polarity transformation

Among the different CEES-indicators which can be included in the HCA-tool, two kinds can occur: (1) those where the higher the value, the better sustainability performance they indicate (positive polarity), and conversely (2) those where the lower the value, the better sustainability performance they indicate (negative polarity). Harmonizing the dataset to facilitate the rest of mathematical procedure is needed, and to that end, the use of the multiplicative inverse or reciprocal transformation, denoted either by 1/x or x-1, is applied to metrics belonging to variables with negative polarity. Hence, all CEES-indicators will follow a direct relationship with the final HCA-tool results, the higher the value, the higher the harmonised circularity performance of the product assessed.

  

### 2.2.2 Scaling

Metrics included in the HCA are often measured at different scales. When trying to create a unified analysis, such differences will result in statistical bias towards those metrics with higher scalar numbers. Therefore, scaling serves as a tool for mathematical processing of indicators with different measure units, allowing their further analysis and comparison. The Normalisation method (MinMaxNorm) is applied in the HCA tool, rescaling values into a range between [0,1], while retaining the proportional distance between data. In normalisation, the minimum value among the evaluated design alternatives for a particular CEES-indicator gets transformed into a 0, while the maximum gets transformed into a 1. Every other value will be a decimal number between 0 and 1, following this equation:

$$X_{norm} = \frac{X - X_{min}}{X_{max} - X_{min}}$$

As a counterpoint, normalisation does not handle outliers appropriately within a specific indicator, as it creates a bounded range [0,1] that entirely depends on the maximum and minimum values in our dataset. As a consequence, outliers have the potential of creating bias by reducing the dispersion of the remaining data. To minimise this issue, two rounds of normalisation are implemented. The first one is applied individually to each dataset of CEES-indicators (intra-normalisation) as previously described. After the rating procedure (see below), a second (inter-normalisation) is carried-out to the whole dataset matrix, which includes all CEES-indicators considered in the HCA.

### 2.2.3 Rating

The goal of the HCA is to aggregate CEES-indicators into a single and comparable indicator ranging from 0 to 1, therefore, there is still the need to define a step to achieve a final single-indicator value of the products assessed. To capture the preferences of the decision-maker consortium members (see section 3), which have specific criteria and background knowledge, each sustainability sphere and their corresponding indicators are submitted to a rating procedure, called weighting for indicators and importance for spheres.

**Weighting:**

The weighting rates process evaluates the significance of CEES-indicators, over the others in a same sphere and for the products analyzed, by using integer values between 1 and 3. To better guide the stakeholder's evaluation process, the following scale, which is aimed to rates according to the stakeholder's own discretion (based in its knowledge background and the supporting information provided), is proposed:

1. Low Importance (LI)
2. Medium Importance (MI)

3. High Importance (HI)

As every stakeholder qualifies each CEES-indicator, there will be as many datapoints as involved stakeholders for every CEES-indicator. Therefore, a measure of central tendency must be used in order to aggregate the qualifications. Such measure could either be the mode or the median, depending on the behavior of the data and the number of samples. The objective is to have a final weight for each CEES-indicator that correctly represents the overall opinion.

**Importance:**

The importance denotes the relevance that each sustainability sphere (circularity, environmental, social and economic) analyzed has over the final single-score. To account for it, each stakeholder uses values between 0 and 100 to qualify the four sustainability spheres, taking into account that the sum of the qualifications should be 100. In this case, the chosen measure of central tendency for the sustainability sphere "x" (after having all the votes) is the proportion that results from the following equation:

$$I_x = \frac{\sum V_x}{S \times n}$$

**Where:**

- $I_x$: Importance weight for sustainability sphere "x"
- $V_x$: Votes (from 0 to 100) for the sustainability sphere "x"
- n: number of stakeholders that participated in the voting process.
- S: number of spheres included in the analysis.

### 2.2.4 Aggregation

To achieve a single comparable indicator as the ultimate goal of the HCA, an aggregation process is necessary to compile the transformed data from different sustainability spheres. The HCA methodology described here utilizes two aggregation steps to fully integrate the CEES indicators. First, an aggregation process combines the already rated and MinMaxNorm normalized indicators for each sphere of the assessed products, based on the 'weighting'. Then, the aggregated values for each sphere are joined by using the 'importance', resulting in a single comparable value that represents the harmonized circularity performance of the assessed product. In other words, the aggregation by 'weighting' generates a final qualification for each one of the sustainability spheres, which is then aggregated by 'importance' to obtain a final single qualification. The aggregation by weighting is done as follows:

$$Q_x = \sum_i \left[ \frac{W_{i,x}}{\sum W_{i,x}} \times X_{norm,i} \right]$$

  

**Where:**

- $Q_x$ : Qualification of the design for the sustainability sphere "x"
- $W_{i,x}$: Weight of the indicator "i" from the sustainability sphere "x"
- $X_{norm,i}$: Normalized value of the measurement for the specific design on indicator "i".

As a result, a percentage value will be obtained. If the evaluated design were to be the best performing one in every CEES-indicator of a particular sustainability sphere, the result will be 1. For every other case, the result will depend on both the normalized value, and the relative importance that each indicator has over the respective sustainability sphere. Subsequent, the aggregation by 'importance', is applied. This is done through a simple weighted average of the previously calculated value Q. Hence

$$Score = \sum_{x} Q_x \times I_x$$

**Where:**

- Score: The final single sustainability score
- $Q_x$: Qualification of the design for the sustainability sphere "x"
- $I_x$: Importance weight for sustainability sphere "x"

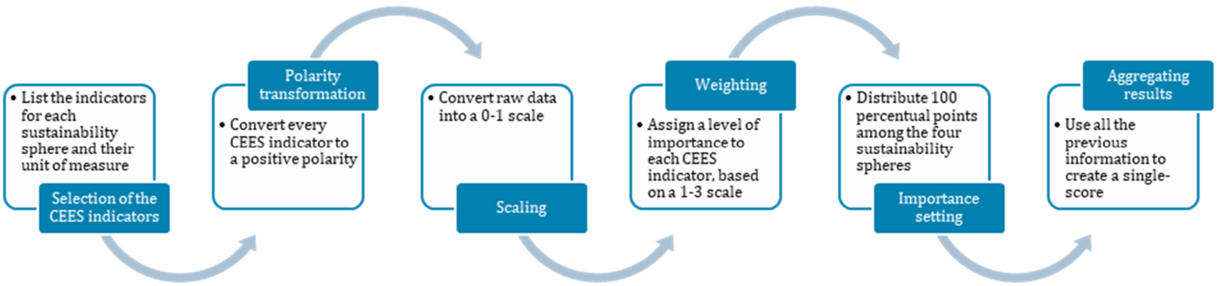


***Figure 6:*** *Methodological summary of the Harmonized Circular Assessment*

## 2.2.5 Final methodological remarks

In the HCA it is important to define the reference product to be considered. Two approaches can be stated (1) internal normalization, which implies that one of the assessed products is taken as reference (i.e., base-case or best-case scenario), and (2) external normalization, which implies that a reference product out of the system assessed is included in the assessed pool (i.e., the average product on the market in a specified time and geographical context). As stated in the proposal, the HCA will be executed on stablished baseline (reference product: Skoda Enyaq and the representative cases) and the different iterative options that may arise during the definition of the best solution, as well as the final ZEvRA representative cases, this is, the internal normalization approach. When internal normalization is adopted, it can only be possible to identify the product(s) which has/have a better harmonised circularity performance among those assessed, but it is not possible to extrapolate the level of sustainability of the product outside the assessed system. Since the results of the HCA are only comparable within the products pool assessed, if new ones want to be compared, it is necessary to follow the same CEES-indicators and rating results (weighting + importance).

  

# 3 HCA rating framework

The rating framework (weighting + importance processes) is planned as a blind process in order not to be biased by the results of the CEES-indicators analysed. To that end, the rating process is done only by knowing the impact categories to be analysed and the products to be compared. Following this approach, supporting information containing the considered CEES-indicators definitions, as well as information regarding each of the products to be analysed and compared (materials, function, system limits considered, etc.) must be provided before the rating process by means of documents, presentations, or other means.

The consortium that will be doing the rating, may be members of the project exclusively, or a mix of project's members and non-members. The second option, which is the one pre-selected for the project ZEvRA, entails publicity and an invitation to out-of-the-project stakeholders. Although this involves inherent difficulties, this offer broader viewpoints which would not necessarily be covered by the project consortium in isolation.

Once informed about considered CEES-indicators and products to be compared, the rating framework participants will have access to the form where they can rate both CEES-indicators (weighting) and spheres (importance) considered in the analysis. Prior to the rating, the form will ask for the kind of stakeholder the participant considers himself. The following categories have been preliminarily selected: Manufacturer / Technical researcher / Environmental researcher / Designer / Supplier / Customer / Legislator / Recycler.

After the end of the period given to the rating process, the responses are aggregated (by means of rounded average) in order to feed the HCA-tool. The aggregation process is done within stakeholders' categories and also among all the respondents in order to get intra-stakeholders rating and consensus rating. These different aggregated rating results allow a deeper analysis of the results and to detect, if any, differences among stakeholders' categories.

  

# 4 Proposed Indicators

In ZEvRA's project, the CEES-indicators to be included in the HCA-tool will have different origins. While the circularity indicators will be determined after a state-of-the-art review, the environmental, economic and social indicators will be those selected for the Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and Social Life Cycle Assessment (SLCA) included in task 1.3. The final selection of indicators will be obtained in collaboration with the implicated project stakeholders from the sustainability assessments, after the baseline results are available to review their relevance. This approach aligns with the current findings of Horizon Europe Transensus[5] that emphasizes the importance of stakeholder collaboration for a better application of LCA, LCC and S-LCA in ZEV's for a more comprehensive and harmonized assessment. As the Transensus project progresses, we will consider future findings to refine our analyses and stay aligned with emerging insights. The following is a list of indicators that could form part of the core list of CEES-indicators:

### Circular

REFUSE

*Variety of materials per product (# of materials)*

RETHINK

*Estimated lifespan (years)*

REDUCE

*% of CRM per product (mass-based)*
*% of non-virgin content of input materials (mass-based)*
*Total mass (kg)*

REUSE

*% of reused content per product (part-based and mass-based)*
*% of reusable content per product (part-based and mass-based)*
*% processing water recirculated internally (volume-based)*

REPAIR

*Repairability index (based on EN 45554)*

REFURBISH

*Upgradeability index (based on EN 45554)*

REMANUFACTURE

*% of remanufactured content per product (part-based and mass-based)*

REPURPOSE

*% of repurposed content per product (part-based and mass-based)*

RECYCLE

*% of recycled content per product (mass-based)*
*Recycled content per product/Potential recycled product (mass-based)*
*% of recyclable content per product (mass-based)*

RECOVER

  

*% processing/car waste sent for energy recovery (mass-based and energy-based)*
*% processing/car waste sent to landfill/burn without energy recovery (mass-based and energy-based)*
*Actual recovery / Potential recovery (energy based)*

DESIGN FOR DISASSEMBLY

*Disassembly depth (cumulative steps to disassemble per part)*
*Fasteners classification (based on EN 45554)*
*Tools classification (based on EN 45554)*

The definitive list of indicators which will be potentially used in the HCA for the circular sphere will be determined in future project's interactions. Regarding the environmental, economic and social aspects will be defined through the development of T1.3 where these topics are studied in detail.

### Environmental

The preliminary list of indicators which will be potentially used in the HCA are those offered by the Environmental Footprint method (EF 3.1), developed by the Joint Research Centre of the European Union. These are:

Climate Change (kgCO2eq)
Ozone Depletion (KgCFC11eq)
Human toxicity – Cancer effects (CTUh)
Human toxicity – Non-cancer effects (CTUh)
Particulate Matter (Disease incidence)
Ionising radiation (kBq U235)
Photochemical Ozone Formation (KgNMVOCeq)
Acidification (molH+eq)
Eutrophication Potential - Freshwater (KgPeq)
Eutrophication Potential - Marine (KgNeq)
Eutrophication Potential - Terrestrial (molNeq)
Ecotoxicity freshwater (CTUe)
Land use (Dimensionless; pt)
Water Scarcity (m3 world eq. deprived water)
Resource Use - Minerals and Metals (KgSBeq)
Resource Use - Fossil (MJ)

For further information about the method and the indicators see PEFCR Guidance [6].

### Economic

The preliminary list of economic indicators is designed to establish a general framework that will be further defined and detailed at a later stage. The economic indicators are:

- Investment cost (€): The initial cost of acquiring and installing the necessary equipment or infrastructure for a project or business venture.
- Production cost (€): The ongoing expenses incurred during the manufacturing or delivery of a product or service, including labour, materials, and overhead.
- EoL cost (€): The costs associated with the end-of-life or decommissioning of a product or asset, such as disposal, revalorizing, or environmental remediation.
- Total cost (€): The sum of all the costs associated with a project or business, including investment, production, and end-of-life expenses.

### Social

The preliminary list of indicators which will be potentially used in the HCA are those offered by the PSILCA (Product Social Impact Life Cycle Assessment) database v.3, a comprehensive database for Social Life Cycle Assessment (SLCA) that provides transparent and up-to-date information on social aspects of products over their life cycles. These are:

**Stakeholder Workers**

Subcategory Child labour

*Children in employment*

Subcategory Forced Labour

*Frequency of forced labour*

*Goods produced by forced labour*

*Trafficking in persons*

Subcategory Fair Salary

*Living wage, per month*

*Minimum wage, per month*

*Sector average wage, per month*

Subcategory Working time

*Weekly hours of work per employee*

Subcategory Discrimination

*Women in the sectoral labour force*

*Men in the sectoral labour force*

*Gender wage gap*

Subcategory Health and Safety

*Rate of fatal and non-fatal accident at workplace*

*DALYs due to indoor and outdoor air and water pollution*

*Presence of sufficient safety measures*

*Violations of mandatory health and safety standards*

*Workers affected by natural disasters*

Subcategory Social benefits, legal issues

*Social security expenditures*

*Evidence of violations of laws and employment regulations*

*Freedom of association and collective bargaining*

*Trade union density*

*Right of Association, Right of Collective bargaining, Right to Strike*

**Stakeholder Local Communities**

Subcategory Access to material resources

*Level of industrial water use*

*Extraction of material resources (other than water)*

*Certified environmental management systems*

Subcategory GHG Footprints and Environmental Footprints

Subcategory Respect of indigenous rights

*Presence of indigenous population*

*Indigenous People Rights Protection Index*

Subcategory Safe and healthy living conditions

*Pollution level of the country*

*Drinking water coverage*

*Sanitation coverage*

Subcategory Local employment

*Unemployment rate*

Subcategory Migration

*International migrant workers in the sector*

*International migrant stock*

*Net migration rate*

*Immigration rate*

*Emigration rate*

*Asylum seekers rate*

*Stakeholder Society*

Subcategory Contribution to economic development

*Contribution of the sector to economic development*

*Public expenditure on education*

*Illiteracy rate*

*Youth illiteracy rate*

*Embodied value-added total*

Subcategory Health and Safety

*Health expenditure*

*Life expectancy at birth*

*Global Peace Index*

**Stakeholder Value Chain actors**

Subcategory Fair competition

*Presence of anti-competitive behaviour or violation of anti-trust and monopoly legislation*

Subcategory Corruption

*Public sector corruption*

  

*Active involvement of enterprises in corruption and bribery*

Subcategory Promoting social responsibility

*Social responsibility along the supply chain*

For further information about the indicators see the PSILCA database[7].

  

# 5 Final remarks/Conclusions

- The simplicity of the methodology's mathematical process facilitates the application and comprehension in ZEvRA and for any other field requiring harmonized circularity assessment.
- Participation and collaboration of all stakeholders is crucial for robust results.

  

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