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Requirements for comparative Life Cycle Assessment studies for single-use and reusable packaging and products comparisons: Recommendation for decision and policy-makers

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Life Cycle Assessments (LCAs) are sensitive snapshots of a products' environmental impact and their findings depend on how they are framed and modelled. Variations in assumptions, functional unit or system boundaries can completely change results and undermine their applicability and final outcome. In the framework of the Circular Economy, particularly important assumptions for reusable and single-use packaging include the number of reuses, weight, sanitising method, transport logistics, and any other aspect which may influence the use phase. In addition, these variables are not fixed over time and may be affected by future changes in product design, consumers' habits or the supply chain management. As a consequence, the impact of different packaging options is not immutable and could change. Therefore, while comparing reusable versus single-use packaging, there is an urgent need to clarify and integrate the methodological requirements necessary to guarantee the reliability of studies and to allow for impartial comparability of results.

Indeed, while it is straightforward to compare two single-use products which go from cradle to grave in one go, it is more complex for products used multiple times, where it is the business model - not the product - which is evaluated. In such cases, rather than evaluating

only one single scenario (e.g., 20 reuses and 50 km distribution distance for the reuse phase), sensitivity and scenario analyses should be used to determine the break-even point. This represents for example the minimum number of times that a reusable product must be used to be considered environmentally better (if at all) than an equivalent number of single-use products. Only these recursive analyses can provide a systemic and comprehensive view. Studies which compare single-use products with reusable options and do not include sensitivity/scenario analyses or break-even points lack robustness and reliability. Unfortunately, we bumped into four recent LCA studies comparing single-use vs reusable packaging where these methodological requirements are only partially satisfied (Figure 1).

Therefore, focusing on the current debate in the European Union (EU) on the Packaging and Packaging Waste Regulation (PPWR), as Members of the European Parliament (MEPs) enter final negotiations on the PPWR, and as the European Council continues to negotiate the text of the Regulation, we are concerned that these and similar studies may influence MEPs' decisions and may set the continent on an unfavourable trajectory for decades and years to come. We urge that, if LCA studies are used to make policy decisions, their methodology must be thoroughly scrutinised before using their results and conclusions. To guarantee its scientific robustness and objective impartiality, it is advised that an LCA study:

1. is a peer-reviewed and independent study conducted using the ISO 14040 and 14044 frameworks. Additionally, prior to public disclosure, the study should be reviewed by an independent third party or by an independently chaired review panel;
2. respects steps laid out in ISO standards. First, the goal and scope definition stage must precisely describe the product/s studied, the functional unit and corresponding reference flows, the scope of the study, the assumptions made for each life cycle stage, the expected audience and the methodology used to calculate impacts. Second, the inventory stage must describe and quantify the inputs and outputs involved in the life cycle of the system studied, by also declaring the data quality and uncertainty. Third, the LCA results should be presented at least in terms of characterised impact indicators. In fact, the impact assessment stage analyses the potential environmental impacts by converting the inventory data into specific impact indicators. This involves various steps, including the mandatory selection, classification and characterization. Fourth, the results should be evaluated in the interpretation stage with the final aim being the formulation of objective recommendations to improve the environmental performance of the system under study. It is emphasised that access to the goal and scope definition and the inventory data (stages 1 and 2 of an LCA) is a non-negotiable prerequisite to validity. This is because even a small variation in the methodological parameters or the inventory can significantly alter results;
3. assesses the highest possible number of environmental indicators. This is possible by the use of a multi-impact analysis method. Some examples are the EU Environmental Footprint (EF 3.0), the recognized method for the Commission Recommendation (EU) 2021/2279 that includes 16 midpoint impact categories (i.e., problem oriented), the ReCiPe 2016 or the IMPACT World+. The latter extends the analysis to 18 impact categories. Among those most used are climate change, resource depletion (water, fossil and mineral), impacts on land compartments (e.g., use and transformation), human toxicity (cancer and non-cancer), an others. Any exclusion of an impact category must be thoroughly justified;
4. evaluates the full life-cycle of the product reviewed, from cradle to grave. Both upstream impacts (e.g., material production) and downstream impacts (e.g., recycling or incineration) must be included in the evaluation;

5. includes clear hypotheses and assumptions on breakage rate, return (trip) rate, weight and end of life strategies (including e.g. recycling performance and quality of the recyclate) both for single-use and reusable packaging;
6. performs a sensitivity analysis and discloses the source of such data, if lower quality data on parameters have been used. The conclusion of this sensitivity analysis should be included in the study, to ensure that the implications of using poor quality data are transparent;
7. considers different business model configurations for the use and end of life phases, alongside clear sensitivity and scenario analyses about, among other, sanitizing types, transport distance, or transport mode;
8. integrates static comparisons with dynamic ones such as the evaluation of the environmental break-even points.

From Figure 1, it immediately emerges that the analysed LCA studies exhibit varying degrees of criticality i.e. they are lacking the fulfilment of the indicated criteria.

We conclude that any report which assesses environmental impacts without respecting the characteristics listed above lacks robustness, reliability and impartiality, and would potentially mislead decision-makers. Therefore, caution should be exercised when considering its results and recommendations emanating from such reports or studies.

Name of the study	*McDonald's study (Kearney)* [1]	*EPPA's study (Ramboll, in-store)* [2]	*EPPA's study (Ramboll, take-away)* [3]	*Tomra's study (Eunomia, take-away)* [4]
Proposed LCA criteria				
Follows ISO LCA frameworks	🔴	🟢	🟢	🟢
Peer-review (i.e. reviewed by third parties)	🔴	🟢	🟢	🔴
Independent (without conflicts of interest)	🔴	🔴	🔴	🟡
Clear goal and scope definition	🔴	🟡	🟡	🟢
Transparency of inventory data	🔴	🔴	🔴	🟡
Inclusion of sufficient and relevant environmental indicators	🔴	🟡	🟡	🔴
Inclusion of full life-cycle	🔴	🟢	🟢	🟢
Clear assumptions on breakage rate, return rate, weight and end-of-life	🔴	🟡	🟡	🟢
Sensitivity analysis on key parameters and assumptions	🔴	🟡	🟡	🟢
Scenario analysis on model configurations for use & end-of-life	🔴	🟢	🟢	🟡
Integration of static comparisons with dynamic ones (break-even points)	🔴	🔴	🔴	🟢

Legend 🔴 Criteria not fulfilled 🟡 Criteria partially fulfilled 🟢 Criteria fulfilled

Figure 1. Visual representation of the analysis of four Life Cycle Assessment studies on single-use and reusable systems for dine-in and food take-away sector. The quality of the studies was assessed in light of the criteria and requirements for robust and methodologically sound analyses.

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