JRC study analysis: why results should be even better for paper packaging.

JRC has performed a study "Exploring the environmental performance of alternative food packaging products in the European Union - Life cycle impacts of single-use and multiple-use packaging issued on February 2024" (hereinafter JRC study) to support the co-decision process of the Packaging and Packaging Waste Regulation (PPWR) by carrying out an LCA to assess environmental impacts of reuse scenarios associated with the reuse targets of the PPWR proposal.

The study represents a significant improvement in practice and balance compared to the version detailed in the slide presentation leaked in September 2023[1].

On the positive side, the study now identifies some of the key uncertainties and assumptions which can influence the results achieved, most notably:

- The recycling rate assumed for single-use systems
- The number of reuses assumed for multi-use systems
- The consideration or otherwise of the use of cars as part of the return trip for reusables

Subsequently, when considering Scenario 1, Scenario 2 CASE a and the Restaurant scenario, it is clear that single-use cartonboard solutions are a favourable option for takeout dining, and that for instore dining they can be environmentally competitive with multi-use plastics solutions when higher recycling rates are achieved.

However, there are still some important and fundamental flaws contained within the study which have a significant influence on the results achieved and the subsequent conclusions drawn. Unfortunately, although the study refers to the International Standards for Life Cycle Assessment (ISO14040 and ISO14044), no external critical review by interested parties has been commissioned as required. Had this been the case, many of the issues discussed below would have been identified and rectified before the study was finalised and published. In particular, the following points relating specifically to Scenario 1 (packaging for cold or hot beverages), Scenario 2 CASE Apackaging for take-away ready-prepared food), and the Restaurant scenario (packaging for a dine-in meal comprising burger, fries and a beverage) must be highlighted (*further explanations regarding each of the points raised are detailed in Annex 1*):

1. **Inappropriate electricity mix:** The electricity mix considered for production of cartonboard is not representative of the European geographical context of the paper mills, an average European electricity mix is considered, but according to important documented sources, production is concentrated in Northern Europe (particularly Scandinavia[2]). Considering an average European electricity mix significantly overestimates by 15-28% the climate change impact for the single use options in Scenario 1, Scenario 2 CASE A and the Restaurant scenario. Applying a Scandinavian electricity mix would further improve the advantage of single use for Scenario 1 and 2 CASE A and would also mean that there is no significant difference in climate change between the single use cartonboard and multi-use plastics solutions for the Restaurant Scenario.

2. **Incorrect water consumption data:** The European average water consumption data considered for production of cartonboard is incorrect and massively overstates the water consumption impact for the single use options in Scenario 1, Scenario 2 CASE A and the Restaurant scenario. If correct data is applied, there is no significant difference in water use impact between the single use and multi-use options.

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1 Supporting the co-decision process of the PPWR: Environmental analysis of Reuse scenarios, Joint Research Centre (JRC) and Sustainable Resource Directorate – Unit D.3, 15th September 2023

2 79% of the virgin cartonboard covered by an average European a life cycle inventory dataset compiled by Pro Carton is produced in Scandinavia. This geographical concentration in the Nordic countries is further confirmed through reference to the industry document Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board

3. **Unbalanced and favourable assumptions for reuse:** The solutions considered are not sufficiently representative, especially in terms of type of packaging selected, lack of preliminary washing and unrealistically low return rates, and subsequently the impacts for the single use cartonboard solutions are overstated and the impacts for the multi-use plastics solutions are understated.

4. **Low recycling rate for cartonboard:** The study considers the following recycling rates: 15% for cartonboard solutions waste and 41% for plastic solution waste. The low recycling rate considered for cartonboard clearly disadvantages single use cartonboard solutions in the analysis, but it is not justifiable in the context of the study. In this respect, the treatment of the single use cartonboard and multi-use plastics solutions is not balanced or symmetric – the cartonboard is penalised with pessimistic assumptions and the plastic is benefitted by optimistic assumptions. This is particularly important considering that the Author's acknowledge that the recycling rate considered is a key parameter for the assessment and can change the results.

5. **Static landfill and recycling rates:** Materials that are not recycled are assumed to go to incineration (45%) or landfilling (55%). This assumption does not reflect the huge uncertainty and variability between countries and its robustness and influence is not directly tested or discussed in the analysis. Different incineration and landfilling assumptions significantly influence the results.

6. **Other impact categories are not considered:** Other relevant impact categories (fossil resource depletion and land use) contribute to the single score results that are presented but are not investigated or discussed. From a fossil resource depletion perspective, the single use cartonboard solutions perform better than the multi-use plastic systems for Scenario 1 and Scenario 2 CASE A. From a land use perspective, the single use cartonboard solutions have a higher impact compared to the multi-use plastic systems but limitations in the land use impact assessment methodology mean that the results should be treated with caution[3]. Single Score results for single use and multi-use would be comparable for Scenario 1 and Scenario 2 CASE A if the Land-use impact category is excluded.

7. **Climate change impacts of polypropylene are underestimated:** The plastics LCI data considered does not reflect latest science. Recent updates to European LCI databases to reflect fully the impacts of plastics production (including e.g. unintended methane emissions during extraction and processing) increase the reported climate change impact of polypropylene by 30%. These improved data are not reflected in the PEF3.1 database used in the JRC study, leading to a understatement by 5% of the climate change impact of the multi-use plastics solutions

8. **Potential bias in the Monte Carlo sensitivity analysis:** Ranges applied for some parameters (including those related to the quality of recyclate attainable by recycling a material) would seem to disadvantage cartonboard in the Monte Carlo sensitivity analysis, but the choice of these ranges has not been justified.

9. **Lacking transparency for some aspects:** Some aspects of the study, such as approaches to end-of-life allocation, lack transparency. This makes it difficult to fully understand the results and the influencing factors.

10. **Approaches inconsistent with the goal and scope:** Overall, the approaches applied are inconsistent with the goal and scope of the study. Caution should be applied when transferring the results of the limited case studies to more complex and interconnected commercial systems.

3 PEF Product Category Rules for Intermediate Paper Products, Ringman et al, 2018

Annex 1

1. The electricity mix considered for production of cartonboard is inappropriate and significantly overestimates the climate change impact for the single use options in Scenario 1, Scenario 2 CASE A and the Restaurant scenario.

In the baseline dataset for cartonboard, a dataset received from industry has been applied, but considering an average European electricity mix for the purchased electricity consumed for board production. This is not reflective of the geographical distribution of the production of food service board in Europe. A significant majority of European food service board is produced in the Nordics. In fact, 79% of the virgin cartonboard covered by an average European a life cycle inventory dataset compiled by Pro Carton is produced in Scandinavia. This geographical concentration in the Nordic countries is further confirmed through reference to the industry document Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board[4]. Due to a higher proportion of renewables, the carbon intensity of grid electricity is significantly lower in Scandinavia compared to the average European grid electricity mix. Subsequently, an analysis by RISE (Research Institutes of Sweden) estimates that the climate change impact of the single use cartonboard solutions is overstated by 15-28%. Such a reduction in climate change results would further improve the advantage of single use for Scenario 1 and 2 CASE A. A 20-28% reduction would also mean that there is no significant difference in climate change between the single use cartonboard and multi-use plastics solutions for the Restaurant Scenario (<15% difference). Applying a Scandinavian electricity mix would also change the BE points identified (regarding number of reuses, recycling rate).

2. The water consumption data considered for production of cartonboard is incorrect and massively overstates the water consumption impact for the single use options in Scenario 1, Scenario 2 CASE A and the Restaurant scenario. If correct data is applied, there is no significant difference in water use impact between the single use and multi-use options.

The industry data applied for the baseline dataset for cartonboard solutions did not include data relating to water use. To fill this data gap, the LCA practitioners applied a mathematical average of the water use data contained in Alt.1 (data for solid board, bleached from the PEF3.1 database) and Alt.2 (a second dataset provided by industry). However, concerns had already been raised regarding the validity of the water use data contained in the PEF entries for cartonboard. These seem to be significantly overstated at approximately 2.3 m^3 world equivalent per kg of board. In contrast, the water use impact for the entry "Corrugated board, uncoated, production mix, at plant, "virgin" Kraft Pulping Process, pulp pressing and drying, flute thickness 0.8- 2.8 mm, R1=0%" is 0.23571 m^3 per kg of board. For the entry "containerboard production, fluting medium, semichemical, production mix, at plant, technology mix, 1000 kg" the water use is 0.18625m3 per kg. For the entry "kraft paper, production mix, at plant, technology mix, kg" the impact is 0.33868m3 world equivalents. All these values tie in with what would be expected for paper. The value of 2.3m3 world equivalents per kg cannot be rationalised. A high-level analysis by RISE (Research Institutes of Sweden) of the Pro Carton virgin dataset considering a range of water scarcity characterisation factors for the mill water use and for the purchased electricity results in a value of around 0.21-0.31 m^3 world equivalents per kg of board (in line with the results for other paper and board entries in the PEF3.1 database). The conclusion is that there is an error in the water use data for solid board entries in the PEF3.1 database. This information was communicated to JRC, but the PEF3.1 solid board, bleached dataset has nonetheless been used for Alt.1 and to create the mathematical average for the baseline dataset. Subsequently, the water use impact for the baseline is overstated in the order of ~55%-60% and in Alt.1 in the order of ~70%. If corrected water use data is applied then there is no significant difference between the single use cartonboard and multi-use plastic solutions for any of the scenarios (Scenario 1, Scenario 2 CASE A and the Restaurant scenario).

4 Suhr, M. et al. (2015) Best Available Techniques (BAT) Reference Document for the Production of Pulp, Paper and Board. doi: 10.2791/370629.

3. The solutions considered are not sufficiently representative, especially in type of packaging selected, lack of preliminary washing and unrealistically low return rates, and subsequently the impacts for the single use cartonboard solutions are overstated and the impacts for the multi-use plastics solutions are understated,

For the cartonboard solutions, the study considers trays (for burgers and fries) made of virgin paper and LDPE lined. According to market information, trays for burgers and fries are made of partially recycled paperboard (more than 60% w/w) and are not LDPE lined. In addition, the study does not consider the use of wraps (for burgers) and fry bags (for fries). Wraps are widely used in Quick Serve Restaurants (QSRs) and are significantly lighter than trays (weight of wraps is about of one fifth of trays). The adopted assumptions may have determined a significant overestimation of impacts of the SU products (both for Scenario 2 CASE A and for Restaurant scenario).

The study did not consider all different items that represent a relevant share of QSR packaging, such as salad boxes, ice cream containers, fry bags and wraps. These latter, as mentioned before, are widely used for burgers and fries, and have a significantly lower weight than trays.

For the multi-use plastic solutions, the study considers a PP cup with a mass of 33g. This appears significantly underestimated. According to market information, the weight of reusable PP cups is in the range 50-120g.

The study does not consider preliminary washing prior to returning items to a collection point. In cases when customers might keep items at home for long time before returning them to the selling point, it is highly likely that items will be washed at home. Even if the preliminary washing only applies to items that are taken home/office, it might have important additional impacts.

Furthermore, the analysis considers that only in 10% of the cases the transport of MU packaging back to the point of sale should be allocated to the packaging products under examination in this case study. As reported by the Authors, impacts of MU packaging are largely influenced by this assumption and significant uncertainty of this parameter can arise. It would therefore be useful considering sensitivity analyses with a higher percentage transported back to the point of sale. Instead, the study considers only one sensitivity analysis related to transport/return scheme with no impacts of transport due to the returning of the MU packaging products to the point of sale, which is unrealistic. This is not justified using any source, and does not seem a reasonable approach particularly considering that:

- drive through – that entails the use of cars – is the main selling channel from QSRs: based on market information, the **drive through market share is higher than 65%.**
- delivery/take away selling channels are generally conducted by means of cars, motorbikes or bicycles; while it can be deemed acceptable that bicycles do not entail impacts, the same cannot be applied to transport with cars and motorbikes.

4. The study considers the following recycling rates: 15% for cartonboard solutions waste and 41% for plastic solution waste. The low recycling rate considered for cartonboard clearly disadvantages single use cartonboard solutions in the analysis, but it is not justifiable in the context of the study. In this respect, the treatment of the single use cartonboard and multi-use plastics solutions is not balanced or symmetric – the cartonboard is penalised with pessimistic assumptions and the plastic is benefitted by optimistic assumptions. This is particularly important considering that the Author's acknowledge that the recycling rate considered is a key parameter for the assessment and can change the results.

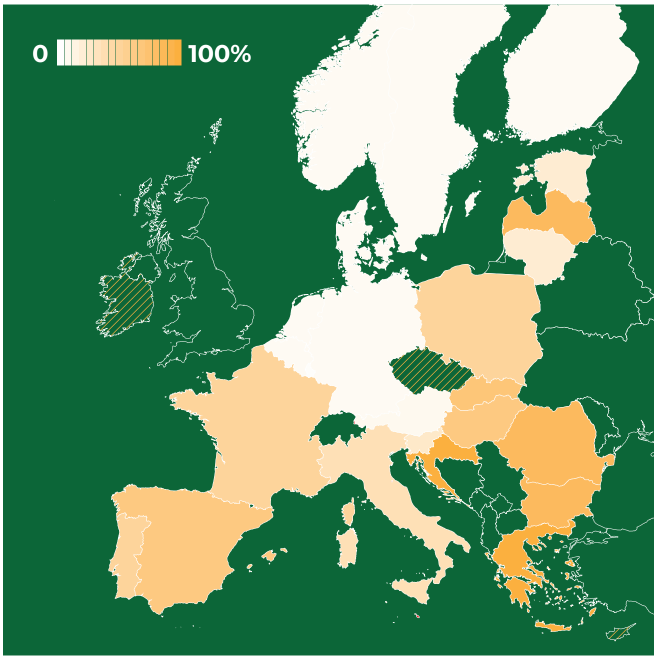
Based on conclusions of the study, End-of-Life (EoL) is a key life cycle stage that may determine significant variation of the result. However, the adopted assumptions for recycling rates and their justification does not appear to be homogenous. For multi-use products Eurostat statistics are considered (41% recycling), while for single use products literature data are considered (15% recycling). The adopted assumption for single use is significantly below Eurostat statistics (82.5%) and market information:

- According to the results of a pilot test conducted by McDonald's in Italy with Comieco (Italian Consortium for the Recovery and Recycling of Cellulose-based Packaging), available in **Annex 2:**
  - The separate waste collection rate achieved in dining room use in McDonald's restaurants can be high and amount to over 80% of the paper products used (including napkins) and 90% of containers.
  - Most of the packaging used in QSRs is pure cellulose - with a high and efficient recycling potential - and a smaller proportion of cellulose packaging is laminated with a double layer of PE, for which standard paper mill recycling is still feasible.
  - Ongoing technological developments in both paper mill processes and packaging design are moving towards a reduction or simplification in the recycling process of cellulose laminates and the use of paper mill process management methods suitable for maximizing their recovery.
  - The quality of the collected paper may have only a minimal portion of foreign material and contaminated cellulose, thus making it potentially rapidly recyclable.
- According to McDonald's statistics in Germany (related to 2022), paper waste collected in restaurants - including tableware and packaging - are almost entirely recycled (source) – **Annex 3.**

The significant influence of considering a low recycling rate for single use cartonboard solutions is shown in the sensitivity analysis which shows that when high recycling rates are considered then even for the Restaurant Scenario single use cartonboard can be preferable to multi-use plastics.

5. Materials that are not recycled are assumed to go to incineration (45%) or landfilling (55%). This assumption does not reflect the huge uncertainty and variability between countries and its robustness and influence is not directly tested or discussed in the analysis. Different incineration and landfilling assumptions significantly influence the results

The adopted assumptions for incineration and landfilling appears not adequate for food packaging. The study considers static rates for the incineration and landfill of materials not recycled (45% for incineration and 55% for landfill), derived from Annex C of the EF method (Zampori and Pant, 2019). These figures, based on overall EU municipal solid waste (MSW) treatment data (Eurostat, 2013) are not adequate to describe food packaging. In fact, these rates are estimated based on the total municipal solid waste (MSW) incinerated and landfilled in the EU (Eurostat, 2013) and cover a wide range of materials and packaging represents a small fraction which is more likely to be incinerated. Moreover, the more recent EU statistics indicate a shift to 54% incineration and 46% landfilling (Eurostat, 2021), with substantial fluctuations between countries. Numbers for the average situation are impacted by very high landfilling rate in Eastern and Southern Europe:



MSW landfill rate (%) in EU countries.
Eurostat (2021)

Therefore, the proportion of non-recycled material sent to landfill and incineration is highly variable and uncertain, but its robustness is not directly tested in the sensitivity analysis. Considering that EoL has a 30% contribution to the overall climate change impact for single use carton solutions, this assumption should have been tested and its influence fully discussed. A high-level sensitivity analysis has been compiled by Stora Enso, considering different regional landfill:incineration rates. The differences between scenarios are notable. The climate change impact for single use carton solutions can be 52% lower in the case of Northern Europe and Central Europe. The consequences of higher incineration share for PP are not addressed, but it would lead to higher emissions (as the emission factor for PP incineration is 1.188 kg CO2-eq/kg). The overall results for Scenarios 1 and 2 CASE A may favour clearly single use carton solutions and the results for the Restaurant scenario may not favour so clearly multi-use plastics over single use carton solutions.

6. Other relevant impact categories (fossil resource depletion and land use) contribute to the single score results that are presented but are not investigated or discussed. From a fossil resource depletion perspective, the single use cartonboard solutions perform better than the multi-use plastic systems for Scenario 1 and Scenario 2 CASE A. From a land use perspective, the single use cartonboard solutions have a higher impact compared to the multi-use plastic systems but limitations in the land use impact assessment methodology mean that the results should be treated with caution5 Single Score results for single use and multi-use would be comparable for Scenario 1 and Scenario 2 CASE A if the Land-use impact category is excluded.

The study claims to have been compiled in compliance with the PEF methodology. However, this is not correct as far as the presentation and consideration of impact categories is concerned. The PEF methodology states that the most-relevant impact categories should be identified. The most relevant impact categories are those which collectively contribute 80% of the single score result, and at least three impact categories shall be identified as the most relevant. The study focuses on only climate change and water use "because of their relevance to the case studies". However, for the single use cartonboard solutions, climate change and water use contribute ~40% of the total single score. For the multi-use plastic solutions, climate change and water use contribute ~45% of the total single score. Other significant categories include fossil resource use (for both single use cartonboard and multi-use plastics and land-use (for single use cartonboard only). No commentary or analysis of the results for fossil resource use and land use is provided in the report – this is not appropriate if single score results are presented and discussed.

Regarding impact category Fossil resource depletion (FRD), This is a high contributor to the single score for both systems (always the second most important impact category), more important than water use according to the PEF method. The single use system performs better than the reuse system from fossil resource depletion perspective for Scenario 1 and Scenario 2 CASE A. So for Scenario 1 and Scenario 2 CASE A, the cartonboard SU option performs better than the MU plastic option for the two most important impact categories, as defined when applying the PEF methodology. But this is not mentioned in the discussion and analysis.

Regarding impact category Land-use (LU), Land use represents ~10% of the single score for the single use cartonboard solutions. However, limitations in the land use impact assessment methodology mean that the results should be treated with caution as the methodology does not appropriately reflect the land-use impact of sustainable forestry practices (resulting in an overstatement of the land-use impact for paper and board products.

Furthermore, because forestry is a process which is quite obviously reliant on a significant area of land for production, there tends to be a focus on more accurate land-use inventory data collection for forestry (and other agricultural) related activities compared to other industrial processes. Subsequently, there may be an asymmetry in the inventory data regarding land-use for board products compared to fossil-based plastics. For example, it is not transparent as to what has been included in the land-use considered for production of fossil-based materials (e.g., land for extraction, land for access roads for extraction, land for adjacent conurbations for housing workers and auxiliary services, land for processing/refining, etc

Single Score results would be comparable (<15%difference) for single use and multiuse in Scenario 1 and Scenario 2 CASE A if the Land-use impact category is excluded. Exclusion of the Land-use impact category would be justified for the reasons stated above.

5 PEF Product Category Rules for Intermediate Paper Products, Ringman et al, 2018

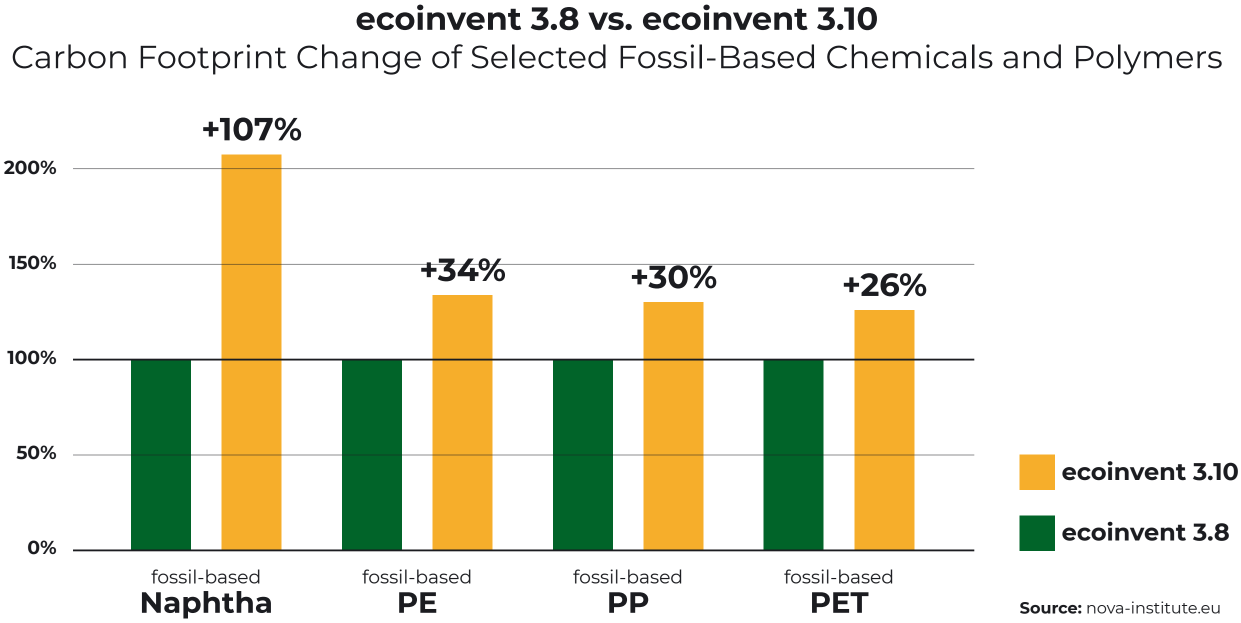
7. The plastics LCI data considered does not reflect latest science. Recent updates to European LCI databases to reflect fully the impacts of plastics production (including e.g. unintended methane emissions during extraction and processing) increase the reported climate change impact of polypropylene by 30%. These improved data are not reflected in the PEF3.1 database used in the JRC study, leading to an understatement by 5% of the climate change impact of the multi-use plastics solutions.

An under-appreciated aspect of LCA studies comparing fossil and bio-based solutions is that while all possible environmental impacts of renewable products are analysed at great expense and included in the LCA, for fossil-based materials the scrutiny is often less stringent. Standard values are frequently applied that do not fully account for regional differences, lack granularity and transparency, and do not take into account a number of impacts on similar level of detail than what is requested for non-fossil alternatives.

The latest updates of the Ecoinvent database, which is the basis for many European LCA's, have started to address some of these imbalances as they include updated data on fossil raw materials and plastics. In Ecoinvent versions 3.9 and 3.10, new data on the supply of crude oil and natural gas have been implemented, which for the first time include unintended methane emissions during extraction and processing. Another highly relevant database in Sphera (GaBi) is also working on updating their data accordingly.

Subsequent improvements have been made to the datasets for the production of chemical pre-cursors and subsequent production of polymers.

The results are a significant increase in the reported climate change impact of polypropylene which will not be reflected in the PEF3.1 database used in the JRC study:



Subsequently, the climate change results for the multi-use plastics solutions are understated by ~5%. Applying the latest LCI data for production of polypropylene would increase would further improve the advantage in climate change results for single use for Scenario 1 and 2 CASE A. It would also narrow the gap between the single use and multi-use for the Restaurant Scenario and would change the BE points identified (regarding number of reuses, recycling rate)

8. Ranges applied for some parameters (including those related to the quality of recyclate attainable by recycling a material) would seem to disadvantage cartonboard in the Monte Carlo sensitivity analysis but the choice of these ranges has not been justified.

There appears to be some asymmetry in terms of the ranges applied for the sensitivity analysis. For example, as well as only considering a very narrow range of recycling rates for single use cartonboard (5-30%) the minimum Q-value[6] considered for single use cartonboard is very low (0.17). In contrast, the minimum Q-value considered for multi-use plastic is much higher (0.8) and the recycling range higher and wider (28-60%). These disparities further highlight the asymmetry in treatment of the single use cartonboard and multi-use plastics solutions. Again, pessimistic assumptions have been applied to the single use cartonboard and optimistic assumptions applied to the multi-use plastics solutions. This may have disadvantaged the single use cartonboard solutions in the Monti Carlo analysis.

9. Some aspects of the study, such as approaches to end-of-life allocation, lack transparency. This makes it difficult to fully understand the results and the influencing factors.

It is stated that the study has been completed in compliance with the PEF methodology. As such the Circular Footprint Formula (CFF) has been applied to allocate impacts between virgin and recycled production. The data considered for virgin production is clearly detailed, but no data is identified for recycled production. It is therefore impossible to judge if the data applied is appropriate and has been correctly applied. Furthermore, it appears that only the CFF approach has been applied. However, ISO 14040/14044 standards require at least two variants of EoL allocation approaches to be evaluated in the sensitivity analysis[7]. This does not appear to have been the case.

10. Overall, the approaches applied are inconsistent with the goal and scope of the study. Caution should be applied when transferring the results of the limited case studies to more complex and interconnected commercial systems.

The study focuses on targets contained in the PPWR (i.e., future 2030 scenario). An attributional LCA approach is applied but to describe a future scenario a consequential LCA approach (which evaluates the consequential impact of a decision) should be used. Furthermore, the PPWR applies at a systems level, but the case studies use a product-specific approach, rather than system-level evaluations. The investigated scenarios will have significant effects on the entire system in which the investigated products perform their functions.

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6 The Q value is factor for quantifying the quality of recyclate attainable by recycling a material

7 From ISO 14044: *"Whenever several alternative allocation procedures seem applicable, a sensitivity analysis shall be conducted to illustrate the consequences of the departure from the selected approach."*