



*Summary*

# Comparative Life Cycle Assessment (LCA)

Summary of the background and results of an LCA of selected beverage packaging types subject to deposit on the Danish market



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## *Summary*

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## **1 About the study**

This summary outlines the most central assumptions and main conclusions from a comparative life cycle assessment (LCA) conducted by the Danish Technological Institute for Dansk Retursystem, in the period April 2025 – March 2026. The purpose of the study is to map and compare the climate- and environmental impacts of selected beverage packaging types included in the deposit system and marketed in Denmark in 2025, including both one-way and refillable beverage packaging. In this context, one-way packaging is defined as single-use beverage packaging that is collected after use and recycled into new materials, while refillable packaging is defined as beverage packaging that is collected, cleaned, and reused multiple times.

This summary presents only the results and conclusions related to climate impact (GWP). The full analysis is documented in the underlying LCA report, which also presents results for a range of other environmental impact categories.

The analysis provides an environmental and climate-related knowledge base based on Danish conditions in 2025. Among other purposes, the results can be used to assess the impacts of different beverage packaging types and to inform discussions on the EU's new requirements under the Packaging and Packaging Waste Regulation (PPWR) concerning the share of refillable packaging at Danish breweries and bottling plants.

The underlying LCA has been subject to a critical panel review by three independent experts in accordance with ISO 14071:2024. The critical review was conducted to ensure methodological consistency with the applied standards and to assess the robustness of the analysis, its results, and the comparisons made. Note that this summary was prepared after the critical review had been completed and has therefore not been submitted to the panel for review.

## **2 Method and scope**

The analysis was conducted as a consequential LCA (C-LCA) in accordance with the applicable requirements and guidelines in ISO 14040/44. The results therefore reflect the total environmental consequences of selecting each individual beverage packaging type, including any resulting market effects. The results reflect average Danish conditions in 2025 and are considered valid for as long as those conditions remain representative. Based on expected developments in the relevant technologies and systems (e.g. the electricity grid, sorting, and transport), the results are expected to remain valid for 3-5 years.

The calculations were performed using the LCA tool OpenLCA version 2.5. The background system was modeled with datasets from ecoinvent v. 3.11. The environmental impacts were calculated using the LCIA method ReCiPe 2016 v1.03, midpoint (H).

The analysis assesses the environmental and climate impacts of the selected packaging types, but it does not include an assessment of economic or social conditions, such as costs, congestion associated with increased transport, or the need for investment in new production and logistics facilities. It should also be noted that the analysis is limited to environmental impacts only, and accordingly, the results cannot be used to assess the overall sustainability of the packaging types.

The data basis consists mainly of primary industry data collected from several Danish breweries and bottlers, packaging manufacturers, the Danish Brewers' Association, and Dansk Retursystem, and is therefore considered representative of average Danish conditions. Transport distances and distribution conditions were calculated as averages based on data from the participating companies. Consequently, it is therefore important to emphasize that the results do not necessarily reflect the specific conditions at individual breweries or bottlers.

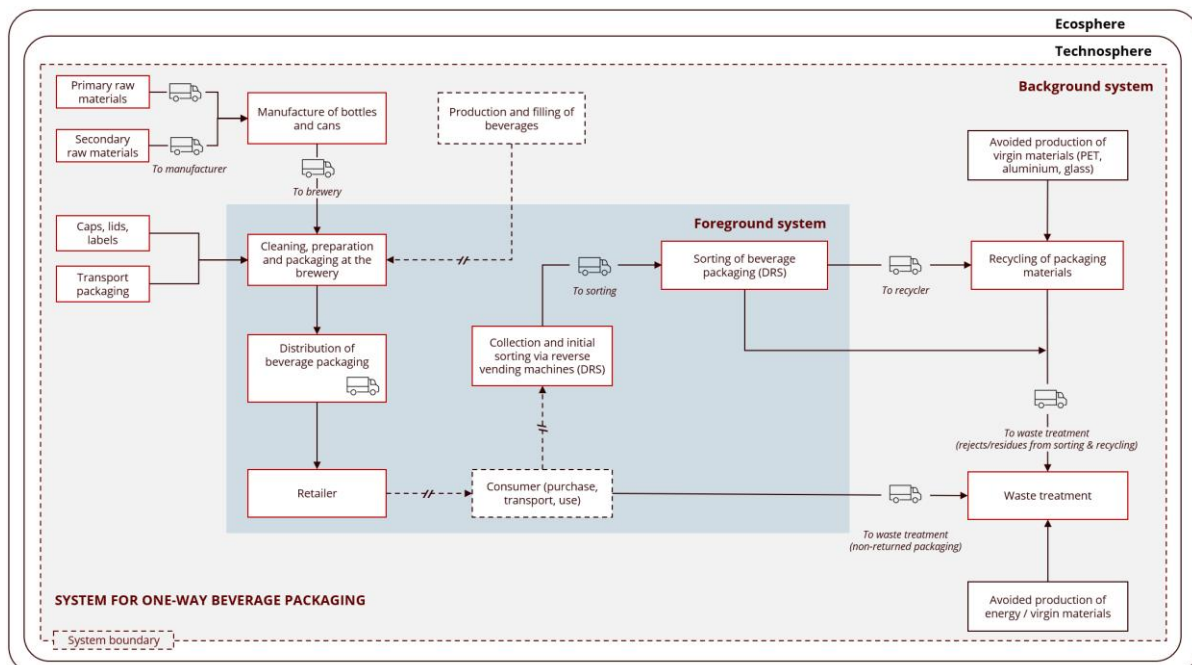
### 3 System description and included beverage packaging types

The life cycle assessment covers all life cycle stages from raw material extraction to disposal (cradle-to-grave), with the exception of the contents of the packaging (the beverage itself), as well as activities occurring during the sale and use of the packaging, such as the cooling of beverages in stores and driving to/from the consumers.

The analysis includes the following phases: 1) manufacturing of materials and containers, 2) transport between producers, breweries/bottlers, distribution links, and collection/sorting facilities, 3) washing and refilling (for reusable containers), 4) collection via Dansk Retursystem and municipal systems<sup>1</sup>, and 5) recycling and waste treatment.

Figure 1 and Figure 2 provide an overview of the main processes in the systems for one-way and refillable beverage packaging, respectively.

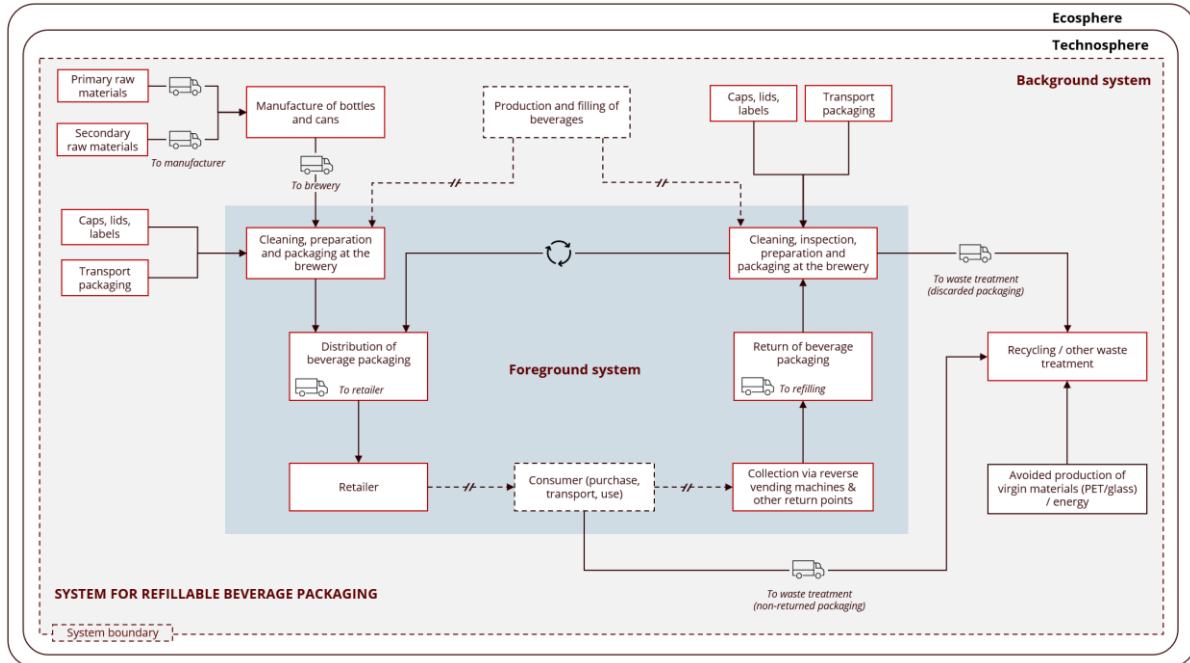
#### Overview of the system for one-way beverage packaging:



**Figure 1**, Simplified flowchart of the system for one-way beverage packaging. Processes marked with a dashed line are outside the system boundary (the beverage itself and activities at the retailer and consumer).

<sup>1</sup> Packaging collected via municipal systems include packaging that are not returned through the deposit system.

**Overview of the system for refillable beverage packaging:**



**Figure 2**, Simplified flowchart of the system for refillable beverage packaging. Processes marked with a dashed line are outside the system boundary (the beverage itself and activities at the retailer and consumer).

Based on data collected from the Danish market, the “trip rate” (in Danish triptal) for refillable glass bottles (i.e. the number of times a bottle is reused) was calculated to be 8<sup>2</sup>. A trip rate of 8 is therefore used as the basis for several of the results presented in section 4 of this summary.

As shown in Table 1, the analysis includes selected types of one-way packaging in glass, PET, and aluminum, as well as refillable packaging in glass and PET. Refillable PET bottles are not currently available on the Danish market, and the results are therefore subject to greater uncertainty. For this reason, the results for refillable PET packaging are not presented in this summary but can be found in the underlying LCA report.

<sup>2</sup> Based on information from Dansk Retursystem and the Danish Brewers' Association. The trip rate is calculated based on data covering 92% of the market in Denmark, and the method used follows the Product Environmental Footprint Category Rules Guidance (EUR-Lex - 32021H2279 - EN - EUR-Lex).



Packaging types and sizes, one-way and reuse system						
Example illustration of packaging types						
<b>One-way beverage packaging</b>						
Container type	Glass bottle		PET bottle		Aluminum can	
Volume [L]	0.275	0.5	0.5	1.5	0.33	0.5
Weight [g]	193	390	22.3	30.6	12.3	17.0
<b>Reusable beverage packaging</b>						
Container type	Glass bottle		PET bottle*			
Volume [L]	0.25	0.33	0.5	1.0		
Weight [g]	255	295	43.0	65.0		
* Currently not available on the Danish market. Results for this packaging type are therefore not included as part of the results presented in this summary, but they are described in the underlying LCA report.						

**Table 1,** Overview of the packaging types and sizes included in the analysis

The selected packaging types and sizes represent the main return groups in the Danish deposit system and are therefore considered representative of a large share of one-way and refillable beverage packaging types in Denmark. However, it is important to emphasize that direct comparisons between all packaging types are not necessarily meaningful. For example, in practice there may be differences in the use of a 0.25 L glass bottle and a 1.5 L PET bottle.

It should also be noted that the results are based on specific variants within the selected packaging sizes in terms of volume and weight (see Table 1) and are therefore not necessarily representative of all variations within those size categories. This is particularly true for one-way beverage packaging in PET and glass, for which there is greater variation in packaging weight.

The analysis has been prepared based on a so-called functional unit (FU), which is both a quantitative and qualitative description of the service or performance provided by a given product or system. The functional unit thus serves as a reference unit and forms the basis for comparing the different alternatives according to how, and how well, they deliver the same function. In this analysis, the number of packaging per FU therefore depends on the volume of the individual packaging variant.

In this LCA, the functional unit is defined as:

***Production, distribution, collection, and waste treatment of the quantity of beverage packaging required to contain and distribute 1,000 liters of beverage on the Danish market in 2025.***



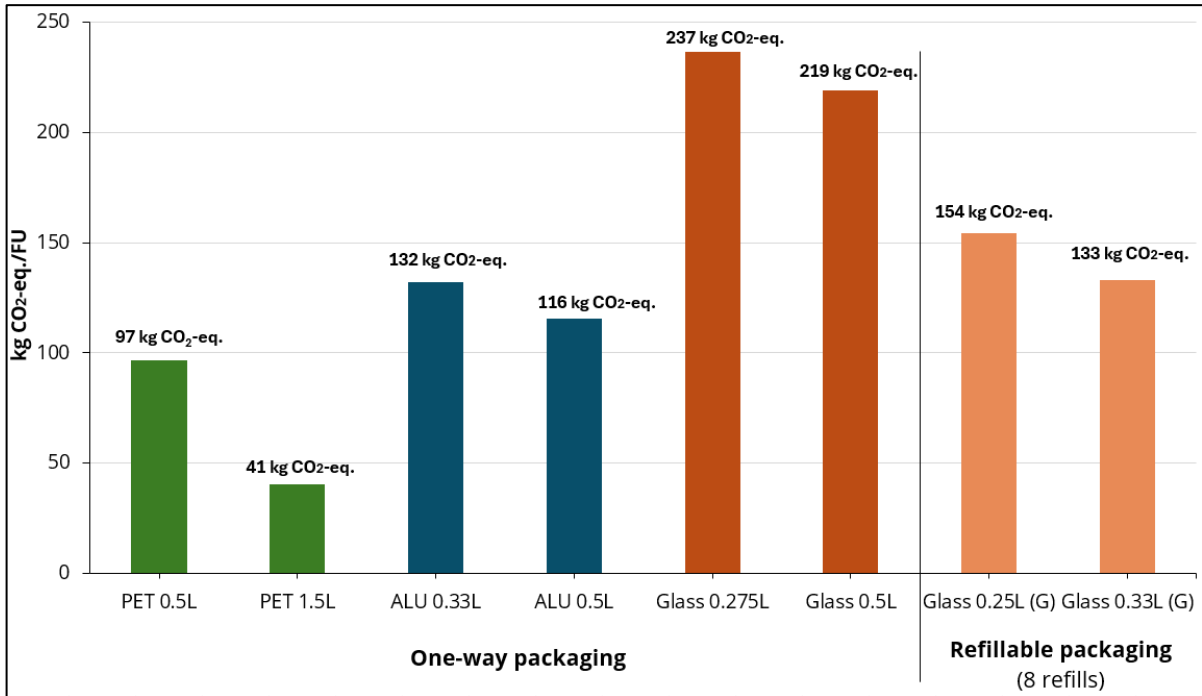
#### **4 Main findings and conclusions**

Selected results from the underlying life cycle assessment are presented in Figure 3 and Figure 4, and the overall conclusions of the analysis are presented in this section. Note that the conclusions below relate exclusively to climate impact (kg CO<sub>2</sub> equivalents). Results for a range of other environmental impact categories can be found in the main report, which provides the basis for a broader comparison of the beverage packaging types included.

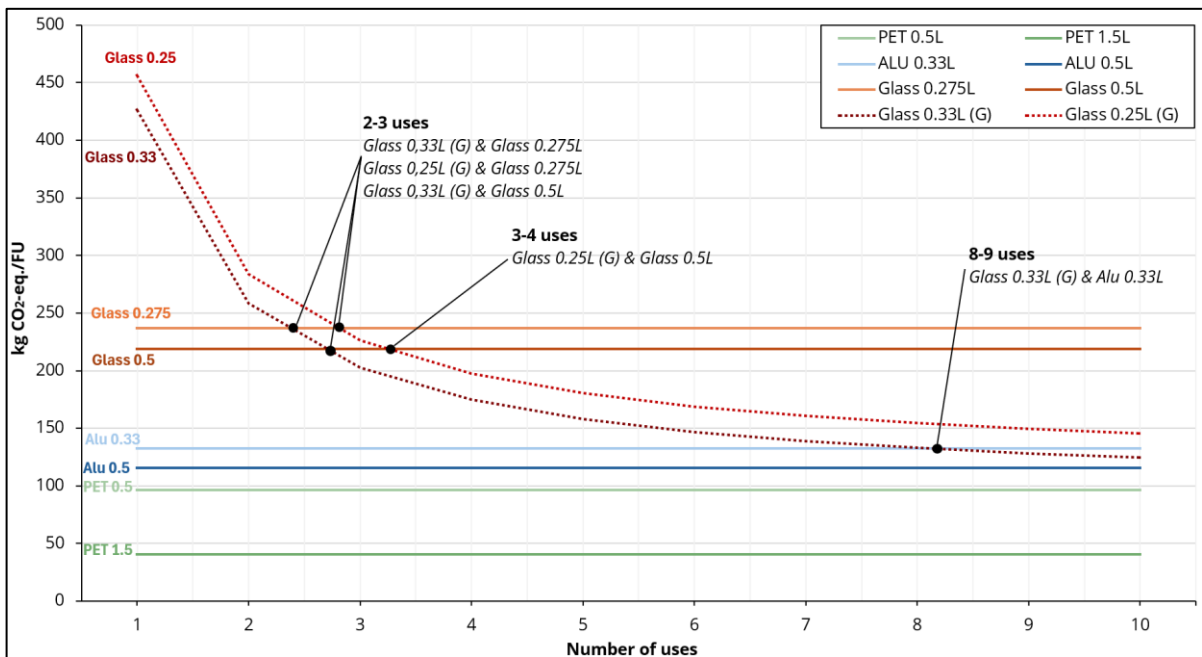
1. Overall, there is no basis for unequivocally concluding that refillable beverage packaging generally has a lower climate impact than one-way packaging in the Danish deposit system, as this depends on the specific packaging types and scenarios being compared. However, the analysis shows large differences in climate impact among the beverage packaging types studied, and a number of sub-conclusions can be drawn from specific comparisons between the individual packaging types.
2. The climate impact of one-way beverage packaging depends on its inclusion in an effective return system with high collection and recycling rates, including bottle-to-bottle and can-to-can recycling. The climate impacts of refillable beverage packaging depend heavily on the trip rate (number of rotations/refills), where a higher trip rate results in a lower climate impact.
3. The transport requirement for glass beverage packaging is generally higher than for aluminum cans and PET bottles, as the latter weigh less per functional unit and can be compressed during collection. Changes in transport distances, transport modes, and truck utilization rates therefore affect the results for glass packaging to a greater extent than those for PET and aluminum packaging.
4. In general, the heaviest packaging types have the highest climate impact per functional unit. This is mainly due to greater material consumption during production and the fact that higher weight also increases emissions from handling, transport, and distribution.
5. Larger packaging sizes (in terms of volume) generally have a lower climate impact within each packaging type because they hold a greater volume of beverage per unit of weight.
6. The one-way PET bottles included in the study generally have the lowest climate impact per functional unit among the beverage packaging types analysed. This is mainly due to their low material weight combined with a high recycling rate in closed material loops.
7. Glass bottles have the highest climate impact among the studied one-way beverage packaging types, especially in the small volume size. This is primarily due to their high material weight per functional unit, which leads to increased emissions from both production and transport.



8. Among the one-way beverage packaging types studied, aluminum cans rank between PET and glass bottles in terms of climate impact. Although aluminum production is energy-intensive, the low weight per functional unit and the high recycling rate help reduce the overall climate impact.
9. Refillable glass bottles achieve a lower climate impact per use as the trip rate increases and can, after a certain number of rotations, reach a climate impact comparable to that of the one-way packaging types studied:
  - After approx. 3–4 use cycles, the climate impact of refillable glass bottles is at the same level as that of one-way glass bottles.
  - After approx. 8–9 use cycles, the climate impact of refillable glass bottles is at the same level as that of one-way aluminum cans.
  - Only at very high trip rates (above 50) does the climate impact of refillable glass bottles approach that of one-way PET bottles.
10. The sensitivity analyses show that the results are particularly sensitive to changes in packaging weight, return rates, and transport assumptions. The climate impact of a specific packaging variant not represented in this analysis may therefore deviate from the results presented. For example, the sensitivity analyses for one-way beverage packaging show that the lightest glass bottles on the market achieve a climate impact on par with that of the heaviest PET bottles, and that the heaviest PET bottle has a higher climate impact than aluminum cans.



**Figure 3** Potential climate impacts of the studies one-way and refillable beverage packaging types at 8 use cycles (trip rate 8). The results are presented as CO<sub>2</sub> equivalents per functional unit (FU).



**Figure 4** Potential climate impacts of one-way and refillable beverage packaging as a function of the number of use cycles (varying trip rate from 1-10). The intersection points indicate the number of use cycles at which the climate impact of refillable glass bottles is at the same level as the respective one-way packaging types. (G) denotes refillable packaging and is shown by dashed curves.